PRISM: Patterns for Reaching and Impacting Students in Math

North Carolina Department of Public Instructions (NCDPI), Carnegie Learning, and WestEd propose a mid-phase EIR project to enhance, scale, and perform a randomized controlled trial (RCT) of Carnegie Learning's *Patterns*, a comprehensive professional learning (PL) program designed to support teachers' content knowledge for teaching and corresponding instructional practices. NCDPI aims to serve historically marginalized groups in STEM (e.g., Black students), students in the lowest achievement quartile, and students from low-income backgrounds.

NCDPI will use its established and trusted network in North Carolina to bring this project to life. This project addresses Absolute Priority 1 (Moderate Evidence), Absolute Priority 3 (Promoting STEM, Science), and Competitive Preference Priority 1 (Promoting Equity with Partners). To address the Competitive Preference Priority, Carnegie Learning and WestEd will each support 3 years of internships from Bennett College (See Appendix C). These will allow students to get valuable experience with education and research companies, which could lead to important connections and interest in related fields for their career.

The proposed study will engage 40 teachers during the formative phases and 300 teachers and 7,500 students in 100 elementary schools in North Carolina during the RCT. This project will allow the improvement and implementation of Patterns, which will increase teachers' self-efficacy, sense of preparedness, math knowledge for teaching, instructional practices, and ultimately students' math achievement.

Section A: Significance

In today's rapidly evolving world, math is increasingly crucial in shaping the future of individuals, communities, and nations. Elementary school education lays the foundation for students' math proficiency, and effective instruction during these formative years is vital. Recognizing the significance of high-quality math education, this proposal argues for the implementation of math content-focused teacher professional learning (PL) for elementary school teachers in North Carolina. By equipping educators with deep math content knowledge and pedagogical expertise, North Carolina can significantly enhance student achievement, foster a positive learning environment, and contribute to the overall improvement of math education.

Elementary school serves as a critical phase in a student's educational journey, providing the building blocks for future mathematical concepts and skills. Numerous studies have demonstrated that a strong mathematical foundation at the elementary level correlates with improved academic performance throughout a student's educational trajectory (Hill et al., 2008; Ma, 2010). A solid understanding of mathematical concepts and procedures equips students with the necessary skills to tackle complex problems, enhances logical reasoning, and nurtures critical thinking skills extending beyond the mathematics classroom (National Research Council, 2001).

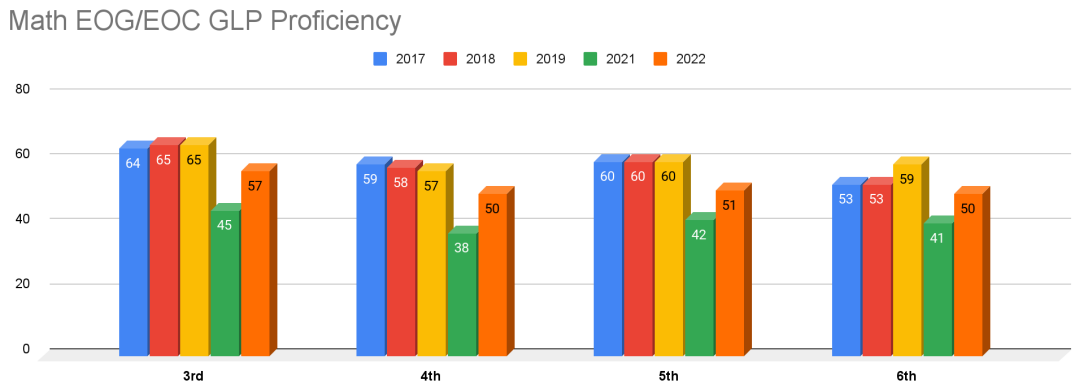
The proficiency rates of elementary and middle school students in mathematics across the United States have reached an alarmingly low and declining level. The ongoing impact of the COVID-19 pandemic has further exacerbated this issue, with students nationwide achieving lower National Assessment of Educational Progress (NAEP) math scores than seen in the past two decades, particularly affecting black students. In 2022, there was a significant decline in NAEP math scores, most notably among minority and low-income students. According to the Department of Education's report on the NAEP scores, the decline among black students was 13 points, compared to a 5-point decrease among white students, which widened the white-black

score gap from 25 points in 2020 to 33 points in 2022. The report also highlighted that lower-performing age nine students experienced greater score declines than higher-performing students, in both reading and math, compared to 2020.

These concerning results are mirrored in North Carolina as well. NAEP scores in the state revealed that students performed five points lower this past year compared to pre-COVID levels. The impact on minority students was particularly pronounced, with only 14% of black students and 19% of Hispanic students scoring proficient on the NAEP math assessment. Similar declines have been observed in state end-of-year test results.

Overall, the data underscores the urgent need for focused efforts to address the declining proficiency rates in mathematics among students nationwide, including in North Carolina. It highlights the persistent disparities in achievement, particularly among minority students. It emphasizes the importance of implementing targeted interventions and instructional strategies to improve mathematics education and ensure equitable outcomes for all students.

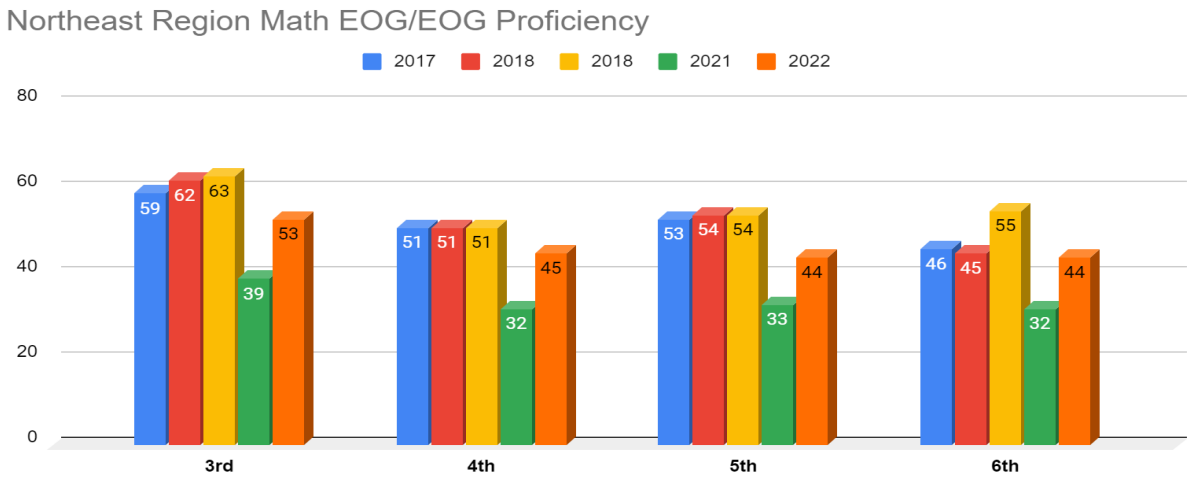
In the three years prior to the COVID-19 shutdown, NC end-of-year testing data showed a gradual increase in the percentage of Fourth-grade students demonstrating grade level proficiency (GLP). Following the shutdown in March of 2020, no State tests were administered. Results at the end of the 2021 school year showed a 21% drop in students demonstrating GLP.



(Source: NCDPI 2022)

This grant intends to provide support to rural regions within North Carolina with higher poverty rates and teacher turnover. North Carolina is divided into 8 State Board of Education regions. Region 1, the Northeast region of the State, exemplifies these characteristics, and student outcomes further demonstrate the need to support teachers. Regional end-of-year testing data is only available starting in 2017, but results show performance below the State average in each year at each grade level.

Both data sets demonstrate a relative flat-lining of student outcomes as the State shifted to new standards and in 2017 and the adoption of the Student Mathematical Practices.



(Source: NCDPI 2022)

The expertise of teachers plays a significant role in influencing students' mathematical achievement. Numerous studies have consistently highlighted a gap in teachers' content knowledge, particularly in the field of mathematics (Ball, Thames, & Phelps, 2008; Hill et al., 2008). In order to effectively identify and address student misconceptions, establish connections between different mathematical topics, and provide meaningful mathematical experiences, teachers must possess a deep understanding of the subject matter (National Council of Teachers of Mathematics [NCTM], 2014).

The COVID-19 pandemic has brought about changes in many math classrooms. The

composition of teachers in school districts has undergone transformations, as districts have faced challenges in finding and retaining qualified teachers for their math classrooms. Consequently, many classrooms now have new teachers, often with emergency credentials and limited formal education training. This lack of experience, as well as specific content and pedagogical knowledge, frequently has an impact on student learning.

For instance, a study conducted in 2010 by Beilock at Columbia University found that math-anxious female elementary school teachers negatively influence the math achievement of their female students. As the majority of early elementary school teachers in the United States are female (>90%), these findings indicate that the anxieties of female teachers regarding math relate to girls' beliefs about their abilities in mathematics (Beilock et al., 2010). Teacher preparation, self-efficacy in the subject matter, and the use of proven instructional strategies are crucial in ensuring that all students receive high-quality learning experiences.

In North Carolina, the lack of teacher preparedness to effectively teach mathematics is prevalent, particularly in rural school districts. The current educational landscape in the state reveals a concerning number of open teacher positions, along with a significant percentage of teachers who are instructing with emergency credentials. This situation underscores the urgent need to address elementary school mathematics teachers' PL needs. Statistics indicate that the attrition rate for North Carolina teachers is 7.78%, meaning there are over 5,000 teacher vacancies across the state and over 7,000 new teachers enter classrooms each year across North Carolina (NCDPI, 2023). This creates an environment where schools are seeking qualified math educators and have significant upskilling needs for new teachers. Additionally, North Carolina is estimated to have over 14k underqualified teachers (Nguyen, Lam, & Bruno, 2022), reflecting a shortage of fully trained and certified teachers in the state. This shortage further exacerbates the issue of teacher preparedness in mathematics education.

Our interactions with teachers and administrators across the state show that many elementary and middle school teachers lack self-efficacy in their mathematical abilities and a solid understanding of effective pedagogical approaches for teaching mathematics. It is important to note that a significant number of teachers have completed only one or, in some cases, zero mathematics teaching methods courses during their teacher training, leaving them ill-equipped to deliver high-quality mathematics instruction.

The impact of this lack of preparedness is twofold. Firstly, many teachers feel apprehensive about teaching mathematics and may inadvertently shy away from providing robust instruction in this crucial subject. This hesitancy can stem from a lack of self-efficacy and a fear of perpetuating misconceptions among their students. Consequently, students are deprived of the opportunity to develop a strong foundation in mathematics during their formative years.

Math content-focused PL programs offer numerous benefits for educators and students alike. By providing teachers with opportunities to deepen their mathematical content knowledge, these initiatives equip them with a robust understanding of the subject matter they are expected to teach (Garet et al., 2001). Such PL experiences support teachers in developing effective instructional practices, including the ability to choose appropriate representations, design engaging tasks, and foster student discourse (NCTM, 2014). Research has consistently demonstrated a positive relationship between teachers' content knowledge and student achievement (Ma, 2010; Hill et al., 2008). Moreover, high-quality PL positively influences teacher efficacy, job satisfaction, and retention rates (Darling-Hammond et al., 2017). In North Carolina, implementing math content-focused PL would serve as an important step in increasing student math achievement.

Our project focuses on the impact of math content-focused PL on teacher content knowledge, self-efficacy, and preparedness and its impact on student math achievement during

the crucial 4th grade year.

Research Based Intervention: Patterns

Patterns serve as a universal language in mathematics. They help us convey complex ideas concisely and precisely. Patterns provide a visual and intuitive representation of math concepts, fostering effective communication and making mathematics more accessible to all learners.

Our goal with our professional learning program, aptly named *Patterns*, is to bring mathematics to life for teachers in a way that makes it easy for them to develop their students into critical, creative thinkers, and problem solvers. Because Patterns is a flexible, hybrid professional learning experience designed to immerse teachers in "model" learning experiences across two semesters, we're able to accomplish three big goals simultaneously:

- **Balance of Mathematical Concepts and Procedures:** To deepen understanding across the most important mathematical concepts and procedures within each grade band
- **Uncover Mathematical Patterns and Develop Fluency:** To uncover mathematical patterns across grade levels in order to make connections to future content (essentially creating fluency in the language of mathematics)
- **Network with Other Professionals:** To build their network of like-minded educators and their toolkit of strategies

Throughout Patterns, teachers will also have the opportunity to gain:

- Exposure to new ideas and strategies that transform math classrooms
- Collaboration with colleagues with access to experts
- Hands-on learning experiences
- Timely personalized learning experiences
- Recognition and validation (develop currency for growing expertise)

Patterns is delivered in two modules over the course of two semesters and is made up of

asynchronous Pattern Building coursework, live virtual Mathematical Discourse & Connection sessions through CL's StudioCast, and On-demand 1:1 Coaching with an expert mathematician. See Appendix J.1 for program screenshots.

The instructional design of Patterns is a consistent, effective 3-week cycle. This cycle happens four times per semester, totaling each module to a 12-week experience for teachers. Week 1 participants engage in synchronous framing and context building through a Live Studiocast. This session will be recorded and shared, while activating and engaging teachers in new learning so they can move confidently into week 2's exploration session through asynchronous concept development. Week 2 will include professional reading and research, and some hands-on virtual manipulatives to help connect concepts to algorithms and procedures. Week 3 is strategically designed to support teachers in a hybrid application and collaborative discourse opportunity. Teachers will have opportunities to test ideas and practice related strategies with their students, share a strategy they tried with their peers, and attend office hours with a math expert. The balance of exploration, collaboration, hands-on experiences, and classroom implementation immerse teachers in growing their math content.

The Conceptual Framework

Our professional learning (PL) framework follows a **Learning by Doing** approach, focusing on the science of learning for adults and students. Through any PL experience with Carnegie Learning, teachers can expect:

- **Problem-Solving in a Learner-Centered Environment**

  Professional learning sessions are structured for educators to experience learning as students would, actively engaging in discourse, hands-on tasks, and critical thinking.

- **Exposure to a Wide Variety of Instructional Strategies**

  Participants will be engaged in a wide variety of instructional strategies, getting the

opportunity to connect them to their own classroom practice.

- **Memorable 'Aha' Moments**

  By periodically asking participants to put their teacher hats back on, they will analyze and reflect on the learner experience, leading to realizations and lessons that stick.

Bruce Joyce and Beverly Showers (2002) research on staff development & student learning identify four main teacher training components: **1) knowledge; 2) demonstration or modeling; 3) practice of the skill under simulated conditions; and 4) peer coaching.**

Joyce and Showers found that when PL is based solely on theory, 10% of participants walk away with knowledge of the topic at hand, 5% will develop some sort of skill set from the PL experience, and 0% will transfer this knowledge and skills into their classrooms in a way that positively impacts student achievement. Demonstrating or modeling the skill in PL greatly helps teachers understand how to connect theory and practice because it explicitly demonstrates that connection in action.

Initial Evidence

Several studies evaluating Patterns have found preliminary evidence of impact. In one study (Fancsali, 2017), teachers in rural Minnesota were administered the University of Michigan's Learning Mathematics for Teaching (LMT) assessment (2011) prior and subsequent to implementation of Patterns in a four-day summer workshop. Analysis of LMT scores showed significant and substantial improvement over this period, $t(17) = 3.93$, $p = .001$. The effect size was large, $d = 0.93$.

A study by the University of Louisville (Jones and Bush, 2009) found substantial increases in teacher content knowledge (as measured by the Algebra Assessment of the Diagnostic Teacher Assessments in Mathematics and Science) following three years of summer Patterns academies for middle school teachers in central Kentucky. Results showed significant

and substantial increases in algebra performance, $t(71) = 13.13$, $p < .001$. The effect size was again large, $d = 1.03$. A study by the state of West Virginia (Stohr, 2013) looked at the impact of a 5-day summer Patterns Academy. Participants were special education teachers in grades 5-12. This study found a significant increase in these teachers' knowledge of proportional reasoning as assessed by the LMT, $t(41) = 2.05$, $p < .05$; $d = 0.4$.

What is still needed is a transition of Patterns materials into a digital medium, which will provide both increased access and more comprehensive coaching during Patterns. What is also needed is further exploration on the subsequent impact of students after teachers have completed Patterns. This project will fill these needs by building and evaluating a scalable and potentially more impactful model of Patterns on both teachers and students.

Section B: Strategy to Scale

B.1 Barriers and Strategies

Patterns' unique evidence-based approach to professional learning has helped mathematics teachers in multiple states to develop critical content knowledge and teaching practices. Preliminary results of studies demonstrate the potential impact of scaling Patterns to teachers; however, there are three main barriers that have previously prevented implementation of Patterns at the scale proposed in this project. They are addressed here.

Barrier 1: Teachers have limited time to devote to face-to-face professional development.

Time constraints create a barrier to engaging large numbers of teachers, particularly in rural schools where there are typically less staff to cover teachers' time out of the classroom. Patterns' new blended implementation structure will offer teachers opportunities for a mix of synchronous and asynchronous engagement that provides the flexibility needed to engage more teachers across broader geographic areas. Similarly, the on-demand 1:1 coaching offers support that fits teachers'

implementation needs as they arise in ways that fit their schedules.

Barrier 2: Effective professional learning requires ongoing coaching and collaboration rather than implementing new strategies in isolation. Patterns' cohort model offers teachers a space and community where they can share and discuss their experiences applying new strategies and learning in their classrooms. It also provides them opportunities to network and continue to grow with a coach, rather than working independently to implement learning from a once-off professional development program. The 3-week cycles, on-demand 1:1 coaching, and office hours with a math expert will ensure that teachers can, but will not have to wait for support, feedback, or opportunities to discuss their experiences with other teachers working on the same things. Additionally, the blended learning approach to these features enables teachers to discuss their implementation ideas with experts and colleagues, rather than trying to put newly learned strategies into practice on their own.

Barrier 3: Face-to-face professional development is costly to deliver at scale. There are many costs involved with enacting face-to-face professional development at scale. Venue and travel costs for both the facilitator and the teachers can be extensive, particularly in rural areas. It can also be difficult to find a convenient location for a large number of teachers to attend, leading to facilitation and follow up coaching costs that may be unreasonably high when only a small number of teachers are reached. The Patterns blended learning model will enable cost effective enactment. Its on-demand coaching will expand the reach of facilitators and coaches and allow teachers to learn and get feedback from almost anywhere.

B.2 Management Plan

North Carolina Department of Public Instruction (NCDPI) will lead the proposed project, collaborating closely with Carnegie Learning and WestEd. Appendix J.2 provides an organizational chart, which illustrates the responsibilities of each staff member and organization.

Figure 1 provides a high-level project timeline, while Table 1 lists the project objectives by year and responsible organization(s). The bolded font for an organization indicates that they are the lead on the milestone. Appendix J.3 provides a **detailed** timeline, with objectives and responsibilities designated for each month of the five-year project.

Figure 1. High-Level Project Timeline, by Objective

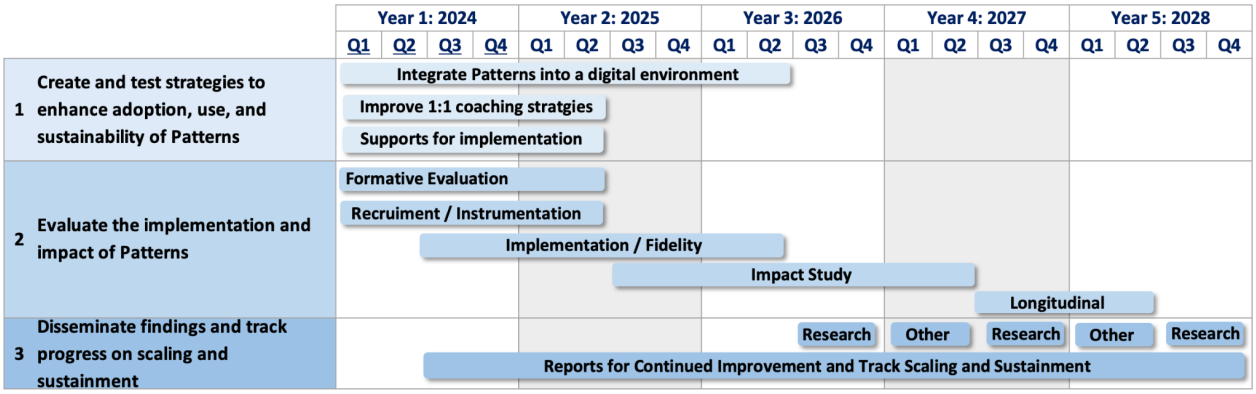


Table 1. Project Objectives and Responsibilities, by Organization and Project Year

Milestone	Y1	Y2	Y3	Y4	Y5	Responsible Organization
Objective 1. Create and test strategies to enhance adoption and use of Patterns						
1.1 Integrate/Improve Patterns materials into a fully digital environment	X	X	X			**CL**
1.2 Build and evaluate 3-week cycle model for PL implementation.	X	X	X	X	X	**CL, WE**
1.3 Evaluate and improve for plan for 1:1 coaching support	X	X	X	X	X	**CL, WE**
1.4 Finalize optimal supports for using Patterns in the classroom.	X	X	X	X	X	**CL**, WE
Objective 2. Evaluate the implementation and impact of Patterns						
2.1. Prepare data collection instruments and procedures and train staff.	X					**WE**, NC
2.2. Identify and randomly assign to treatment and control conditions.	X					**WE**, NC
2.3. Measure and assess implementation fidelity of Patterns.	X	X	X	X		**WE**
2.4. Measure and assess the impact of Patterns.		X	X	X	X	**WE**
Objective 3. Disseminate findings and track progress on scaling and sustainment						
3.1. Disseminate findings to research audiences.			X	X	X	**WE**, NC
3.2. Disseminate findings to public, teacher, and policy audiences.				X	X	**WE**, NC, CL
3.3. Support adoption and track cost, scaling, and sustainment.		X	X	X	X	**WE**, NC, CL

B3. Capacity to Bring the Project to Scale

The NCDPI, Carnegie Learning, and WestEd are very capable of bringing the proposed project to scale. If funded, the NCDPI will hire a full-time project manager to guide and coordinate the identification and participation of schools and teachers and to lead internal project management. The project manager will coordinate with IT and school personnel and to assist with support tasks as needed. In addition, the NCDPI will provide for necessary state level leadership to liaison with district superintendents and with state level leadership. The NCDPI Math Section Chief will coordinate with the K-12 state level math team to collaborate on specific math content and pedagogical strategies. The NCDPI team has also identified research and evaluation staff to support Carnegie Learning's assessment of student outcomes.

WestEd is a preeminent educational research, development, and service organization with over 900 employees and 13 offices nationwide. WestEd has been a leader in moving research into practice by conducting research and development (R&D) programs, projects, and evaluations And other activities. Over the past five years, WestEd has carried out almost 2,500 successful projects representing major contributions to the nation's R&D resources. At any given time, the agency has between 450 and 700 active contracts and grants. WestEd staff on this project will include senior personnel with expertise in math education, online and game-based learning, formative and summative evaluation, advanced quantitative methods and statistics, and research implementation. These staff have a proven track record of successfully executing projects of similar complexity, scope, and focus, including multiple large scale, multi-site RCTs.

Carnegie Learning is a leading provider of K-12 education technology, curriculum, and professional learning solutions. For more than 25 years, they have channeled leading research into tools and technology that champion teachers and build lifelong learners. They have launched and supported several education initiatives at scale, such as MATHia, whose impact has shown to

have ESSA Tier 1 and Tier 2 levels of evidence (Carnegie Learning, 2023). They have already supported Patterns at scale, reaching over 5,000 teachers across 45 districts in 19 states. Their personnel have expertise in development, implementation, and scale of education programs, and also the knowledge to use research findings and enact them for continuous program improvement.

Table 2 provides details on the capabilities of the key personnel and their project roles. NCDPI will be responsible for managing the project and ensuring progress on meeting objectives. They will also share responsibility for recruiting, onboarding, and implementation monitoring. Carnegie Learning will lead development while WestEd will lead a series of formative evaluation studies to improve new features and administration models. Carnegie Learning will implement all training and support of its product. WestEd will be responsible for leading the independent impact evaluation and leading implementation fidelity analyses. All parties will contribute to dissemination of study activities and findings.

Table 2. Roles, Responsibilities, and Relevant Experience of Key Project Staff

Staff and Role	Primary Responsibilities and Relevant Experience
North Carolina Department of Public Instruction Key Personnel	
Dr. Michael Maher, Deputy State Superintendent, is a former teacher, faculty member in teacher preparation, and assistant dean in a college of education. Dr. Maher has a range of experiences that include 1) teaching, 2) research and evaluation, 3) assessment and accreditation, 4) strategic planning and program development, and 5) policy development and implementation. He will serve as the key point of contact for OESE, CL, and WE, and oversee the NCDPI staff and partner relationships. **Dr. Charles Aiken**, Section Chief: Mathematics, Science and STEM, has extensive academic leadership experience, and will lead the identification, onboarding, and support of schools in the study. **Dr. Jeni Corn,** Director of Research and Evaluation, has extensive experience in conducting research in school settings and providing technical assistance to school, district, and state-level education staff focused on research, evaluation, and policy in the southeast. Dr. Corn will coordinate research activities with WestEd and staff from NCDPI, including data collection and dissemination.	
WestEd Key Personnel	
Dr. Steven Schneider is the Senior Director of STEM Research and Entrepreneurship at WestEd, and brings decades of experience managing large-scale research projects and Center grants. Schneider will serve as WestEd's Principal Investigator, key point of contact, and manage the project and partner relationships. **Dr. Scott Strother**, Senior Research Associate II	

in Math, is the evaluation lead in two EIR grants and has extensive project management experience. He will assist with project management and lead the development of measures, collection processes, and analyses of implementation data. **Ms. Nanette Seago**, Senior Program Associate in Math, has extensive experience in researching and running large scale studies on the impact of PL and will lead the formative study design aspects related to the PL. **Dr. Catherine Paolucci**, Senior Research Associate in Math, is an experienced mathematics educator with an extensive record of leading and researching professional learning focused on content knowledge development and effective teaching strategies. She will help direct the impact study. **Dr. Kevin Huang** is a Senior Research Associate at WestEd. He brings expertise and extensive experience in applied statistics and psychometrics and has led many research and measurement projects funded by the USDOE and NSF. Huang will lead the quantitative data analysis in all stages of the study.
Carnegie Learning Key Personnel
Dr. Steve Ritter, Chief Scientist, has decades of experience developing and researching CL programs including multiple federal grants. He will serve as CL's Principal Investigator, key point of contact, and manage the project and partner relationships. **Peter LaCasse**, Chief Strategy Officer, has been an education administrator and has designed and launched education offerings. He will lead the program development and adjustment based on formative feedback to achieve maximum impact. **Kasey Bratcher**, Chief Services Officer, has a proven track record of developing and managing high-functioning, multi-layered teams, and expanding in-person and digital services. She will allocate and coordinate the CL staff on the project to ensure they have the appropriate skills and strategies to achieve project goals.

B4. Dissemination Plan

To reach research, policy, and practitioner audiences interested in issues related to implementation and impact, we plan to present research findings at national research conferences (e.g., American Educational Research Association, Society for Research on Educational Effectiveness, etc.) and publish findings in peer-reviewed journals (e.g., Journal of Research on Educational Effectiveness, Educational Researcher, etc.). In addition, WestEd, the research partner, will submit presentations with at least one math leader from North Carolina to national practitioner or policy annual conferences (e.g., National Council of Teachers of Mathematics, Innovative Schools Summit, National Rural Education Association, etc.). WestEd will also highlight key findings through all of its communication networks (e.g. WestEd.org, Insights blog, R&D Alert Online, WestEd E-bulletin, etc.)

Carnegie Learning has a robust communication and dissemination structure in place to support leveraging the study's findings. Carnegie Learning plans to disseminate the findings in the following ways:

- Internally and externally to help design future professional learning (PL) programs, ensuring they are effective and aligned with educators' needs.
- Improving current offerings: Insights from the study will be used to enhance existing curriculum, instructional materials, and learning platforms.
- Informing educators through published communications: Articles, blogs, reports, and other publications will be used to share the study's evidence and inform educators about its findings.
- Collaborating with teachers in the Patterns Program: Close collaboration with teachers in North Carolina's Patterns Program will help apply the study's findings directly to their needs.
- Internal sharing of findings: The study's insights will be shared internally with over 150 PL staff members to enhance training and support services nationwide.

By implementing these strategies, Carnegie Learning aims to enhance their programs, support educators, and contribute to evidence-based practices in education.

The NCDPI will promote findings around Patterns broadly within the state and across other states using its collaboration through the Council of Chief State School Officers and other partners. The NCDPI, and its state superintendents have a strong communication capacity and related experience, such as the Superintendent's Polaris 2.0 Strategic plan, the Accelerate/Invigorate/Motivate conference and partnerships with institutions such as the North Carolina Center for the Advancement of Teaching (NCCAT). NCDPI will leverage tools, including websites, newsletters, virtual and in-person conferences, social media, and direct outreach to interested state leaders.

B.5: Utility

The proposed project's resulting evidence-based implementation plan of a virtual Patterns training will help bring a proven professional development sequence to a much broader audience. The current program has reached over 5,000 teachers across 45 districts in 19 states. With the proposed adaptation, particularly following the formative research and improvements, Patterns will become more flexible to fit the needs of a wide variety of teachers, including rural teachers where travel may be difficult. The resulting implementation model will be designed so the program can scale quickly and effectively across North Carolina and to other states. Its blended 3-week cycle structure and on-demand coaching will provide a more cost-effective approach to high-quality professional learning that offers teachers greater support for learning, classroom-based implementation, and real time feedback. The study will also contribute to the overall knowledge base regarding best practices in online math PL, particularly around math content knowledge and related teaching practices.

Section C: Project Design

C.1 Conceptual Framework Underlying the Research

Patterns aims to create and support a learning environment that is known to have strong success. This environment is labeled as Inputs in the Logic Model (see Appendix G). Patterns has then generated a theory that identifies four high-leverage drivers that contribute to increasing teacher knowledge, self-efficacy, feelings of preparedness, and effective instructional strategies. These drivers are live Mathematical Discourse and Connection sessions, on-demand 1:1 coaching, an information tracking system, and follow-up workshops. The logic model represents these four drivers as Output Activities, which lead to teacher engagement and participation and builds towards key teachers and student outcomes (see Table 3).

Table 3. Key evidence in support of each driver.

Conceptual Framework for the Impact of Patterns
Live Mathematical Discourse and Connection sessions
These sessions combine exploration, hands-on experiences, and collaboration (Desimone, 2009; Loucks-Horsley et al., 2010). Sessions use active learning to engage teachers in the same discourse and activities their students will experience and prepare them to use hands-on virtual manipulatives to explore the concepts underlying algorithms and procedures (Darling-Hammond et al., 2017). The synchronous format allows facilitators to adapt and respond to questions, ideas, and challenges in real time, building trust and creating a safe environment for teachers to share and reflect on their beliefs and practices (Borko et al., 2014). Mathematical discourse can positively impact how students engage in mathematical thinking and learning (Zahner et al., 2021). As teachers better understand the conceptual underpinnings of what they teach, they are more likely to be comfortable fostering mathematical discourse that encourages students to share ideas and discuss varying approaches to solving problems (Bishop, 2016; Hill et al., 2005).
On-demand 1:1 Coaching
Patterns' expert coaching model provides teachers real-time feedback and assistance as they integrate their learning into their classroom practice (Darling-Hammond, 2017). This personalized, job-embedded approach offers teachers sustained support as they transform their new knowledge into lesson design, instruction, and assessment (Garet et al., 2001). It can address individual questions, concerns, and challenges and helps teachers effectively adapt their implementation of new mathematical knowledge and strategies to support the unique learning needs of their students (Croft et al., 2010; Sowder, 2007).
Information tracking system
Patterns draws on information and analytics from teachers' engagement with activities to customize instruction and support. Each teachers' support team (facilitators, coaches) can monitor their progress and provide individualized or full-group support, as appropriate, to work through difficult new concepts, ideas, and practices. This information tracking also offers valuable insight into teachers development of new knowledge, including how they learn best (Goldsmith et al., 2014).
Asynchronous Patterns Building Coursework
Teachers then complete asynchronous work, where they have the flexibility to work at their own pace through interactive activities, videos, readings, discussion boards, assignments, reflection, and formative assessments. This asynchronous work provides "time for teachers to think about, receive input on, and make changes to their practice by facilitating reflection and soliciting feedback." (Darling-Hammond, 2017). Feedback and ideas from others working to implement similar learning in their classrooms creates a sense of community that helps teachers learn and grow within a collaborative professional community (Adams et al., 2018, Desimone, 2009).

C.2 Project Goals, Objectives, Outcomes, and Measures

This project aims to evaluate the efficacy of Patterns in at least 50% rural schools serving high-need students. We expect that the project will reach approximately 7,500 students with 300 teachers in grade 4 across 100 schools throughout North Carolina. To achieve the goals and objectives described in Table 1 (see B.2), we propose to (1) build Patterns into a fully digital environment, including connections sessions, 1:1 coaching, an information tracking system, and workshops; (2) implement and test the efficacy of Patterns in our high-need sample; and (3) disseminate findings and track progress on cost and sustainability. A table detailing a full set of tasks and timelines towards these proposed project goals, objectives, and measures is seen in Appendix J.3.

C.3.a Population Description

For this study, we define high-need students as "students at risk of educational failure or otherwise in need of special assistance and support, such as students who are living in poverty, who attend high-minority schools . . . [or] who are far below grade level" (US DOE, 2012). North Carolina has nearly 1.5 million school students enrolled in over 2,500 schools. Over 100,000 students participate in 4th grade math each year. The state has a diverse population of students, including more than 50 percent minority students, and over 42% percent of its schools are classified as rural (see Tables 4 and 5). Over half of the schools in this study will be schools classified as rural, as defined by an urban-centric district locale code of 32, 33, 41, 42, or 43.

Table 4. North Carolina Schools and Student Distribution by Region Type

Region Type	*City*	*Suburban*	*Town*	*Rural*
Percent of schools	26.2%	19.4%	12.3%	42.1%
Percent of students	28.6%	23.8%	10.5%	37.0%

Source: NCES (2016).

Table 5. North Carolina Public Education Enrollment, by Race / Ethnicity, 2021-2022

Race / Ethnicity	*AI / AN*	*As*	*Bl*	*His*	*Haw / PI*	*Wh*	*Multi*
Percent of students	1.3%	3.3%	25.2%	17.9%	0.1%	47.9%	4.2%

Source: NCDPI (2023).

Note: AI / AN = American Indian/Alaskan Native; As = Asian; Bl = Black; His = Hispanic; Haw / PI=Hawaiian Native or Pacific Islander; Wh = White Non-Hispanic; Multi = Multi-Ethnicity.

North Carolina has 58% economically disadvantaged students (NCDPI, 2020). Additionally, 2020 NAEP data showed that only 35 percent of 4th grade students in North Carolina were performing at or above proficient (NCES, 2022).

C.3.b How Patterns Will Address Teacher and Students Needs

As discussed in *Section A: Initial Evidence*, the Patterns program has shown success with over 5,000 teachers across 45 districts in 19 states. The program has and will improve its tools to address the varying needs of teachers and students across diverse settings. As discussed in *Section B.1*, moving to an online medium to enhance access, lower cost, and bring more diverse teachers from wider contexts together will only enhance the potential impact of Patterns. The 3-week cycle model provides opportunities for collaborative work, trials with students, and ample expert coaching for all teachers. These practices have been shown to improve teachers' self-efficacy and feelings of preparedness, which can enhance their instructional practices (see C.1). A broad range of students from this large teacher sample will be impacted by their teachers' well-supported classroom-based implementation of instructional approaches with increased conceptual understanding. This can lead to improved student mathematical learning and achievement, including increased standardized test scores, which can then scale to teachers across that nation that serve high-needs students.

Section D: Project Evaluation

WestEd will conduct an independent evaluation of the implementation and impact of Patterns on 5th grade math teacher and student outcomes (see Table 6) with the impact study designed to meet WWC standards without reservation (see D.1). Following extensive formative evaluation (see D.4), the impact study will use research questions (RQ) 1–4 to study the impact of the intervention on teacher and student outcomes, including a WWC acceptable state standardized test for student achievement. Questions 5 and 6 address implementation and are designed to provide both performance feedback during initial stages and to document key factors that should be considered during replication and further scaling of Patterns. Questions 7–9 explore mediating and moderating effects, which will unpack how key project components and contextual factors can influence outcomes. Questions 10–11 are exploratory but will provide evidence of sustaining impact of Patterns and could provide evidence of replicability, respectively.

Table 6. Evaluation Research Questions and Data Sources

Research Question	Primary Data Source(s)
Impact analyses	
1. What is the impact of Patterns on students' math achievement?	North Carolina 5th Grade End-of-Grade Assessment
2. What is the impact of Patterns on teachers' math content knowledge?	Learning Mathematics for Teaching Project (LMT)
3. What is the impact of Patterns on teachers' self-efficacy and feelings of preparedness?	Teacher Sense of Efficacy Scale (TSES); Scales from PTPE
4. What is the impact of Patterns on the nature of teachers' instructional activities?	Instructional Activities scales (on a study-administered teacher log)
Implementation analyses	
5. To what extent is Patterns implemented with fidelity? How do teachers perceive the professional learning?	Training sign-ins, observations, Patterns teacher data, teacher logs
6. How does the implementation and completion of Patterns differ across contexts, such as school and teacher characteristics? What factors hinder or facilitate the implementation and completion of Patterns?	Training sign-ins, observations, Patterns teacher data, teacher logs, relevant background and demographic data
Main mediating and moderating analyses	
7. To what extent does the impact of Patterns differ across school contexts, teacher and classroom characteristics, and student characteristics?	All data for RQs 1–4, including relevant background and demographic data

8. To what extent is the impact of Patterns on student outcomes mediated by instructional activities?	All data for RQ 1
9. To what extent is the impact of Patterns mediated by the fidelity of implementation?	All treatment data for RQs 1–4
Exploratory analyses	
10. Is the impact of Patterns on student success similar the second year after PL completion?	All data for RQ 1
11. After the control teachers are trained, are their outcomes comparable to the outcomes of the original treatment group?	Same data as RQs 2-4

These research questions align with the project's objectives and strategies and will be addressed using data collected from 100 elementary schools in diverse settings across the state of North Carolina (see C.3).

Impact Study. Half of the 100 schools will be randomly assigned to have their 5th grade math teachers participate in Patterns and the other 50 schools will continue with business-as-usual professional learning (PL) and instruction (see D.1). Recruitment will target schools with a high percentage of high needs and underserved students, but will ensure an appropriate range of demographics for generalization. The sample will consist of all 5th grade teachers and students in participating schools. This design will allow participation from approximately 300 teachers (150 in each condition) and 7,500 students for the impact study. The control teachers will be offered Patterns following the impact study. The proposed study is powered for a minimum detectable effect size of 0.11 to 0.12 for student outcomes, and 0.28 to 0.32 for teacher instructional activities. (See Appendix J.4 for details about the power analysis and Appendix J.5 for details about the hierarchical linear models for the impact analyses.)

WWC Acceptable Outcome: Student Math Achievement. To measure students' outcomes for RQ1, WestEd will use the North Carolina 4th Grade End-of-Grade Assessment, which is considered valid and reliable by the WWC standards. The assessments were developed by a rigorous standards setting process to ensure high validity and reliability (NC DPI 2021).

Students' course grades will be used as a supplemental, exploratory measure of student achievement. Because grading practices differ from teacher to teacher, course grades will not be interpreted as a precise measure of student learning. Rather, they will be interpreted as a marker of course performance, which is policy relevant and a strong indicator of future academic success (Allensworth & Clark, 2020).

Outcome: Teacher Math Content Knowledge. To measure teachers' mathematical knowledge needed for teaching, WestEd will administer a measure of mathematical knowledge, developed as part of the Learning Mathematics for Teaching (LMT) Project, both before and after the PL sequence. With the LMT, "a teacher may be required to provide an explanation to a mathematical rule or procedure, examine an unusual method for solving a problem, or decide which of several definitions is accurate and usable with students at the grade level she teaches" (LMT, 2004). The LMT has shown strong internal psychometrics around validity and reliability, including reliability scores for the included outcomes ranging from 0.72 to 0.81 (Hill, 2004). The LMT has also been used successfully in prior studies of Patterns (e.g. Stohr, 2013).

Outcome: Teacher Self-Efficacy for Instructional Strategies and Student Engagement. The Teacher Sense of Efficacy Scale (TSES) is a validated 24-item survey with three subscales, two of which are aligned with the current study: efficacy in instructional strategies and student engagement. The survey will include the 16 items from these two relevant, highly reliable subscales ($\alpha > 0.87$; for example, see Page et al., 2014) (items in Appendix J.6).

Outcome: Teacher Feeling of Preparedness. We will use the Knowledge and Strategies sub-scales from the Pre-Service Teachers' Sense of Preparedness survey (Abraham et al, 2021). These scales measure teachers' feeling of preparedness in both the math content knowledge required for effective teaching as well as the corresponding skills of implementing effective

teaching strategies. The scales were shown to have strong reliability ($\alpha > 0.88$) and face and content validity (items in Appendix J.6).

Outcome: Teacher Instructional Activities. To measure the quality of instructional activities (RQ4), WestEd will administer a teacher log three times across the year during the impact study to provide an accurate picture of the instructional activities over the entire school year. Prior studies of teacher logs indicate that they can be a valid and reliable measure of instruction (Rowan & Correnti, 2009). The log will include the following measures adapted from a RAND study of inquiry-based instruction (Le et al., 2006): inquiry-based practices intended to actively engage students and promote problem solving skills ($\alpha = 0.83$), inquiry-based activities intended to facilitate critical thinking ($\alpha = 0.77$), discussion ($\alpha = 0.74$), and developing conceptual understanding ($\alpha = 0.58$). Together, these measures capture the types of instructional activities expected to be seen in conjunction with Patterns in the classroom (see Appendix J.6 for the complete set of items). In addition, WestEd will perform at least 80 observations of treatment and control classrooms during the impact study, with the aim of our observation sample including at least half of the schools.

D.1 Meeting WWC Standards Without Reservations

The evaluation of the impact of Patterns will be based on a school-level randomized controlled trial designed to meet What Works Clearinghouse recommendation standards without reservations (WWC, 2020). Participating schools will be assigned to the treatment or control condition using blocked random assignment. Blocks will consist of school-level demographic information and prior math End-of-Grade Assessment outcomes (see Appendix J.5).

After randomization, Patterns will begin enrolling teachers in the treatment group into its PL sequence. All teachers in the treatment schools who plan to teach 5th grade math in the

coming year will be included. Treatment schools will receive Patterns's PL program and those teachers will have full access to all of its resources.

The control schools will administer business-as-usual math classes and will not have training with or access to Patterns. Their PL will include regular offerings from the NCDPI, whose Mathematics Team provides Public School Units (PSU) with support related to the implementation of the K-12 Mathematics Standard Course of Study. Support may include regional PL opportunities, virtually or in person, with math consultants as requested through regional case managers from District Regional Support.

School-level random assignment was selected since schools typically implement Patterns as a school-wide program, in which all math teachers receive PL and access to resources. Second, a teacher-level assignment would raise the threat of contamination, as teachers in a school may discuss, view, and share instructional materials and strategies. Also, based on prior school-level randomized studies (Davenport et al., 2019), particularly with NCDPI's support, we expect minimal school-level attrition during the impact study.

The analysis of the intervention's impacts will use an intent-to-treat (ITT) approach—schools and their teachers and students will be retained in their originally-assigned groups. Student rosters will be collected at the start of the 2026-27 school year to identify students in the ITT student impact sample. To get a comprehensive assessment of the instructional activities students experience during the study, the primary impact analysis for teacher instructional activities will estimate ITT effects. Given that the proposed evaluation is based on a school-level RCT that is expected to have low cluster-level attrition and a student analytic sample where joiner bias is not a threat, the evaluation has the potential to produce strong evidence about the impact of Patterns. Students who join the school after randomization will not be included in the analytic sample. In addition, based on research (Kim et al., 2020; Taylor & West, 2020) and

WestEd's prior RCT experience, we anticipate manageable levels of student attrition during the study (i.e., less than 20%) and minimal differential student attrition across conditions (i.e., less than 5 percentage points), so the student impact analyses will likely meet WWC standards without reservations (see WWC attrition White Paper; WWC, 2017).

D.1.a Generalizability and Scalability. In partnership with NCDPI, WestEd can evaluate Patterns across a large number of economically disadvantaged schools, particularly in high-minority and rural settings. Findings based on this diverse study sample will provide valuable guidance for future replications of program implementation as the program scales further across North Carolina and throughout other states with similar populations. To inform generalizability, the evaluation will include a set of moderator analyses (RQ6) to assess the extent to which the effects of Patterns are moderated by the characteristics of students, teachers/classrooms, and schools. Results from these analyses will guide future efforts to scale Patterns, as they may identify where the program is particularly effective or less suited and how it can be improved accordingly. Appendix J.5 lists the potential moderators and corresponding analysis plan. Furthermore, analyses will explore how implementation and instructional practices mediate the direct effects on students' math achievement.

D.1.b Cost Effectiveness. The evaluation includes a cost analysis based on the Resource Cost Model (Levin & McEwan, 2002) to provide information about the cost of implementing Patterns, including associated PL and support, and whether it is cost effective relative to the BAU condition. Implementation and PL costs will be identified in both the Patterns and BAU conditions using the "ingredients method" (Levin et al., 2017). Analyses will identify the costs associated with each component of the program, distinguish start-up costs from ongoing costs, and convert total costs to per-student costs. We will then combine the cost information and effect

size estimates to describe the impact of Patterns on a per dollar basis following the most up-to-date recommendations for cost analyses (Cost Analysis Standards Project, 2021).

D.2 Strategies for Replication

Our approach aims to make findings generalizable so they may impact the most students as the program scales. To this end, our research questions explore how, when, and for whom Patterns is working. Patterns has been successfully used in the last 6 years with 5,000 teachers across 45 unique districts in 19 states across the US (from California to New York to Florida); however, evaluation of the new online implementation, including moderation and mediation analyses, have not been completed. This project will fill this important knowledge gap.

Additionally, with the measures and methods developed by this study, replication and on-going research can occur to ensure that the program is working for all teachers and students, and deficiencies can be identified and corresponding improvements made. Patterns' approach to entry using district-wide or larger partnerships also makes the program scale quickly, which can provide future opportunities for such studies. With the findings from this study and future studies, Patterns will be able to identify areas for cost-effective improvements and will be better able to address any barriers to implementation found across various contexts. Patterns will prioritize continued research and improvements using its own funds and potentially through other partners and grant monies.

D.3 Components, Mediators, Outcomes, and Acceptable Thresholds of Implementation

The design of the proposed evaluation is informed by clearly articulated key components, mediators, and outcomes of Patterns as depicted in the conceptual framework presented in Appendix G. The impact analyses (RQ 1-4) will be based on valid and reliable measures: (1) North Carolina 5th Grade End-of-Grade Assessment, (2) Learning Mathematics for Teaching (LMT), and (3) Instructional Activities scales. The evaluation will include moderator analyses

(RQ7) and mediator analyses (RQ 8-9) to explore the relationships among implementation context, intermediate outcomes, and student achievement outcomes, as discussed above. Implementation context data will be collected from multiple sources, including artifacts (e.g., sign-in sheets and agendas) from teacher trainings to determine participation and coverage, observations, interviews, and monthly teacher logs describing teaching activities using Patterns and other curricular materials. Acceptable thresholds of implementation will be accounted for within PL measures, teacher logs, and observations. Thresholds will most likely be based on tracking the percentage of weeks in which teachers attended and completed the expected number of activities prescribed in the administration model (see *Section A: Patterns Components*). These thresholds will be specifically defined during the formative evaluation stages (see D.4), and will be monitored to discover if the program is implemented with fidelity and what potential effect the level of fidelity may have on outcomes.

D4. Formative Evaluation, Performance Feedback, and Periodic Assessment of Progress

During the first one and a half years of the evaluation, performance feedback and periodic assessment of progress will be addressed through formative evaluation. Usability studies, a classroom feasibility study, and a classroom implementation study will build towards the impact study (see Table 7), and will be guided by the corresponding research questions in Appendix J.7.

Table 7. Summary of the samples and timeline for each major evaluation component.

	Usability	Feasibility	Implementation	Impact
Timeline	Summer 2024	Fall 2024	Spring 2025	2025-2027
Teachers	10	10	20	300
Students				7,500

Usability Study. In summer 2024, WestEd will conduct multiple rounds of usability research, as needed, to iteratively test new program components, features, and content that were built in the

winter/spring by Carnegie Learning. For each round, at least 5 teachers will participate with a minimum of 10 different total teacher participants. Research has shown that this is a sufficient number of testers to identify major issues, and that testing with additional users provides diminishing returns (Nielsen, 2000). The sample of these studies will be intentionally balanced with regard to demographics and contexts. WestEd researchers will guide participants through the relevant tasks and ask them to "think aloud" and explain their thought processes as they go. At the end of each session, WestEd will interview participants about their overall experiences, the ease of use of the activities, and their understanding of the tools and content presented. Each round of usability will result in a qualitative summary of findings **with actionable recommendations to Carnegie Learning.**

Feasibility Study. In fall 2024, WestEd will conduct a feasibility study to evaluate whether teachers can use the professional development components and materials, and translate them into practice, as intended in an authentic education setting. Another main goal will be exploring how teachers envision ideal usage of Patterns, to inform possible administration models for the Implementation Study. WestEd will complete the feasibility study with 10 teachers, each with one full class of students. Teachers will participate in two 3-week cycles of Patterns and attempt corresponding classroom practices. Through interviews and observations, WestEd will capture data related to the implementation and potentially effective models. Feedback will be collected from teachers through a weekly log and a final interview. Qualitative and quantitative reports of findings will provide **actionable recommendations to Patterns** throughout the year.

Implementation Study. In spring 2025, WestEd will conduct a 3-month implementation study of Patterns, to test four 3-week cycles. The study will involve 20 teachers, each with one full class of students. WestEd will perform two observations per classroom and teachers will complete

monthly logs and a final interview. The implementation study will result in a mixed qualitative and quantitative summary of findings, **with actionable recommendations to Patterns.**

Performance Feedback and Periodic Assessment of Progress. During this formative period, WestEd will help develop the ideal administration model in partnership with Carnegie Learning and NCDPI that can work best for teachers in North Carolina. WestEd will also create measurable thresholds for acceptable implementation in consideration of teacher feedback and findings from the implementation study.

The formative evaluation will also provide structure for consistent, periodic feedback to NCDPI on the progress of Carnegie Learning towards its development goals within Patterns. All parties will participate in virtual, bi-monthly calls to discuss upcoming project goals and review progress to date on development, testing, and other project components, as detailed in the Detailed Project Timeline and Management Plan by Project Objectives and Performance Measures (see Appendix J.3). WestEd will be responsible for monitoring and tracking all activities and reporting to NCDPI, to make sure all goals stay within their scope and timeline. Any deviation or concern on progress or performance will be discussed among all stakeholders, including the Program Officer.

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