Game-Based Learning:

Immediate Feedback from Real Time Data and Differentiated Instruction

Enhance Students' Mathematical Learning

Jiawen Chen, Ph.D.

Nicole Zelem, M.Ed.

Joshua Prieur, Ed.D.

Lisa Kilanowski, D.Ed. (Ed.)

Abstract

Continuous monitoring of students' progress in their math learning is associated with higher levels of mathematics achievement. Progress monitoring gives students more control over their own learning. It also enables teachers to identify students who may not benefit from general classroom instruction (e.g., struggling or excelling students) and facilitates adjustment for individualized instruction. As an innovative educational tool, digital game-based learning simplifies the implementation of progress monitoring by collecting learning data in the game and making monitoring results immediately available to both teachers and students. Teachers can proactively modify their classroom instruction on a timely basis to meet the changing needs of their students. The facilitation of continuous progress monitoring and differentiated instruction are two ways through which digital game-based learning can help enhance math learning for students.

For teachers and school administrators there is an increasing emphasis on the academic success of every student, as exemplified by the *Every Student Succeeds Act (ESSA)* introduced in 2015 by the Obama administration. This challenge to improve the overall achievement of their students is made more difficult by the diversity of the student population today, their varied academic abilities, and limited resources available to school personnel. To overcome these obstacles, it is imperative to systematically and cost-effectively gather informative data on individual student performance and progress (i.e., progress monitoring) so that evidence-based differentiated instructional practices can be implemented to meet the unique needs of each individual student (Ysseldyke & Bolt, 2007). The integration of technology into classrooms greatly facilitates progress monitoring at both the classroom level and the student level, making it possible to have immediate feedback data available for both students and teachers. Research shows that technology-enhanced progress monitoring systems and data-driven instructional decision-making significantly improves students' mathematical learning (Brosvic, Dihoff, Epstein, & Cook, 2006; Faber, Luyten, & Visscher, 2017; Foegen, Jiban, & Deno, 2007; Kickmeier-Rust, Hillemann, & Albert, 2014; Ysseldyke & Tardrew, 2007).

Among the technologies available to students and teachers for classroom integration, game-based learning technology has received a lot of attention from both educators and education researchers. Game-based learning technology not only enhances motivation and engagement for students, but also provides an efficient way for teachers to monitor student performance and to access comprehensive data for modifying classroom instruction. Compared to the traditional pen-and-paper formative assessment, game-based learning technology can organize and report information on student performance and progress immediately and offer various forms of data visualization to help teachers better understand the information.

Benefits of Progress Monitoring for Student Learning

One of the theorized benefits of progress monitoring is that teachers can use the information collected on a frequent basis to keep aware of every student's performance and progress, thereby facilitating changes in instruction for students encountering roadblocks in their learning (Ysseldyke & Bolt, 2007). In a large-scale randomized control trial that included 2,202 students ranging from Grades 3 to 10 in 125 classrooms in 24 states, Ysseldyke and Tardrew (2007) examined the effect of a progress monitoring system, Renaissance Learning, on mathematics test performance over one semester. Students completed math questions generated by the system which were set by teachers and were aligned with curriculum. Both students and teachers received immediate feedback on student performance. In addition, teachers were alerted when students struggled with certain assignments and were provided with information for differentiated instruction. Results showed that students who were treated with this program experienced significantly more gains in the posttest than those who did not receive the program. The difference in gains between the two groups of students over one term was 14% in 3rd and 4th Grade.

In another study by Faber and colleagues (2017), the authors explored the effect of a digital formative assessment tool with a sample of 1,808 Grade 3 students in the Netherlands. The students who received the treatment completed assignments on a tablet device whereas the students in the control condition completed the assignments with traditional pen and paper. For those in the treatment condition, both teachers and students received immediate feedback. Teachers were able to follow students' progress and adjust their assignments accordingly. The findings demonstrated that students in the treatment condition outperformed their counterparts in the control condition after one semester, and greater usage of the progress monitoring tool were related to

better test performance. In addition, students who had greater usage of the progress monitor tool also reported stronger motivation to learn math.

The benefit of progress monitoring is accentuated when aided by real-time data that allows for immediate — instead of delayed — feedback. For example, when comparing 40 3rd Grade students identified as having a mathematics learning disability to another 40 typically-achieving students, Brosvic and colleagues (2006) found that immediate corrective feedback, but not delayed feedback, improved learning outcomes for students with learning disabilities. In another study that examined the efficacy of math apps on tablet devices, Zhang and colleagues (2015) also found that immediate feedback, a prominent feature of math apps that are hard to achieve in pen-and-paper format, contributed to the reduced achievement gap between struggling students and their classmates. Immediate feedback provides a sense of control during learning, letting students know the correctness of their answers without delay, and also provides them with opportunities to have a second try if they did not get it right the first time.

An important function of progress monitoring is to let teachers detect students for whom general classroom instruction does not promote adequate learning. In particular, education researchers have been keen to understand how progress monitoring, with either immediate or delayed feedback, may help identify students with learning disabilities who need additional support (Brosvic et al., 2006; Foegen, 2008; Fuchs, Fuchs, Compton, Bryant, Hamlett, & Seethaler, 2007; Fuchs, Fuchs, & Hollenbeck, 2007). For students with learning disabilities general instruction in class may be too hard to follow. On the other hand, progress monitoring could reveal high-achieving students for whom general instruction may be too easy. In a study that examined the effect of progress monitoring (with immediate feedback) on enhancing math learning for gifted and talented students, Ysseldyke and colleauges (2004) recruited 100 gifted and talented

students between 3rd and 6th Grade — 48 assigned to the treatment classroom with progress monitor technology and 52 to the control classroom with traditional teaching method. While both groups did not differ in pretest scoring, after implementing the progress monitor system for one semester, students in the treatment condition scored significantly higher in the posttest. Furthermore, while the two groups did not differ in the number of practice items attempted, students in the treatment condition correctly answered more items than students in the control condition. Having immediate feedback on their answers allows students to dictate the pace of learning and enables teachers to adapt their instruction to match the students' skill levels.

The needs of both high-achieving and students who struggle may often not align with general classroom instruction. A lack of progress monitoring data impedes teachers' ability to provide differentiated instruction. As Nicolae (2014) stated: "Differentiated instruction is meant to fill the gap between teaching and learning" (p. 430). The misalignment between teaching and learning could lead to students becoming less motivated and less engaged in their learning. Using real-time data to facilitate progress monitoring helps accommodate these students' needs and permits teachers to provide individualized skill level matching instruction.

Differentiated Instruction and Enhancing Student Learning

Differentiated instruction has been proposed as a key solution to meet the learning needs of the diverse student population present in today's classrooms (e.g., skill level, learning abilities, second language, ethnic and cultural differences; Suprayogi, Valcke, Godwin, 2017), while also helping students achieve optimal learning outcomes. Differentiated instruction is a pedagogical approach that accommodates students' diverse learning needs by applying differentiated teaching strategies in practice and sustaining their use over time (Nicolae, 2014). For example, for stu-

dents who are struggling, differentiated instruction might involve the implementation of more practice questions, or explaining a concept using multiple modalities to increase comprehension. For students who are excelling, they may receive instruction on more advanced topics, or delve deeper into content they have already mastered. Differentiated instruction is characterized by its flexibility, adaptiveness, and student-centered orientation (Ismajli & Imami-Morina, 2018). It is more than simply grouping students by their ability. On the teacher side, it takes into consideration the course content, pacing of lessons, mode of teaching, and skill level. On the student side, it considers learning style and interest (Park & Datnow, 2017).

Differentiated instruction can trace its theoretical root to the famous psychologist Vygotsky (1978) and his idea of the "zone of proximal development." This term suggests that for a student to learn, the knowledge to be mastered needs to be moderately more advanced than the student's current level of knowledge. The student would struggle to acquire the new knowledge by him or herself, but through the process of scaffolding and support from teachers, parents, and peers, the student would be able to succeed. At the same time, the knowledge to be mastered should not be too advanced such that it makes learning impossible even with scaffolding and support. Because there are varying levels of student readiness and learning style within a classroom, each student has his or her unique zone of proximal development. To optimize the learning outcomes for each student, teachers need to adapt their teaching to individual students' learning zones.

Research has shown that differentiated instruction positively impacts student success. In one study, for example, 4th and 5th Grade students who were assigned to a differentiated instruction group that used curriculum based on students' strengths and interests and were tailored for diverse learners had significantly higher mathematics achievement compared to students in the control group receiving the traditional curriculum (Tieso, 2005). This positive effect of differen-

tiated instruction on math achievement was found among college students as well (Chamberlin & Power, 2010). Grimes and Stevens (2009) also showed that the use of differentiated instruction was positively associated with math motivation and confidence among a group of 4th Grade students that were comprised of both high- and low-achieving students. In addition, employing differentiated instruction predicted higher student engagement, interest, satisfaction (Johnsen, 2003), and greater motivation and learning enthusiasm (McAdamis, 2001).

For differentiated instruction to be effective, several conditions need to be met. First, teachers need to take a proactive, rather than reactive approach to plan for differentiated instruction (Tomlinson et al., 2003). This means instead of making minor modifications to general lessons designed for the whole class, teachers need to plan lessons that account for student differences from the outset. Simply tinkering with a one-size-fit-all lesson plan may not be enough to achieve the desired outcomes of differentiated instruction (Tomlinson et al., 2003).

Second, teachers need to be flexible with their use of small learning groups in the classroom (Tomlinson et al., 2003). Research shows students in small within-classroom learning groups had significantly higher levels of academic achievement than students not in learning groups (Lou, Abrami, Spence, Poulsen, Chambers, & d'Apollonia, 1996). Grouping should be based on student readiness, learning needs, interest, and model of learning.

Third, the educational materials and pacing of lessons need to be aligned with student needs (Tomlinson, 2003). Instead of assigning the same set of practice questions and advancing the curriculum at the same rate for the whole class, these decisions need to consider individual students' readiness and learning style.

To meet these conditions for effective differentiated instruction, it is critical that teachers differentiate their students which requires teachers to have comprehensive knowledge about the students' ability levels. Moreover, this knowledge must be updated regularly, especially for mathematics education. This is because a student could be doing well one week in one skill component (e.g., addition and subtraction) but struggle the next week in another skill component (e.g., multiplication and division). Without close monitoring, the teacher may not be able to detect the problem in time and, consequently, fail to apply appropriate instruction to address it. Obtaining accurate and up-to-date formative assessment data that can help determine student ability in a convenient, non-labor-intensive way is one of the biggest challenges teachers face when implementing differentiated instruction.

Progress monitoring with immediate feedback made possible by digital technologies could greatly enhance teachers' ability to differentiate their students. As reviewed in the previous section, progress monitoring lets teachers detect students for whom general classroom instruction does not promote adequate learning. The availability of immediate feedback data keeps the information up to date. Research shows that teachers who used progress monitoring technology and adapted their instruction according to the feedback spent more time providing individual instruction than group instruction and they felt they were better able to meet individual students' learning needs (Ysseldyke & Tardrew, 2007). In addition, their students significantly outperformed students in traditional classrooms on mathematics tests (Ysseldyke & Bolt, 2007; Ysseldyke & Tardrew, 2007). In their meta-analytic study, Gersten and colleagues (2009) noted stronger effect of ongoing feedback on achievement for special needs students than for general education students. The authors explained that this observation may be attributed to special edu-

cation teachers using feedback information to set individualized goals, which is particularly important for this group of students.

How Does This Relate to Prodigy Math Game?

Prodigy Math Game is an innovative digital game-based learning product that aspires to make learning math fun for students through its immersive game environment, attractive graphics and engaging gameplay. Along their journey in the game, students must defeat monsters and bosses by correctly answering math questions that match their abilities. Among its many features is the mechanism to provide immediate feedback to students on their answers. If the first attempt was unsuccessful, students have another opportunity to solve the problem. This design offers a meaningful learning experience to students, allowing them to work out their mistakes without delay. In the process students are afforded time and autonomy over the pace of their own learning.

Prodigy Math Game also records and synthesizes learning data from students and generates comprehensive reports for teachers. Teachers can access reports on the performance of the class as a whole or reports of individual students broken down by skill components (e.g., fraction, geometry). Various forms of data visualization (e.g., percentage bars and charts) are available for the reports to maximize data utility for teachers. Such detailed information enables teachers to track their students' learning progress and implement differentiated instruction that targets specific students and skills. Because Prodigy Math Game matches its in-game math problems to students' abilities, the assessments paint an accurate picture of each student's successes and struggles. In addition, since Prodigy Math Game reports are based on real-time data of student per-

formance, teachers can be confident that their instructional adjustment is timely and meets their students' immediate needs.

Conclusion

Game-based learning technology has the ability to administer formative assessments to students and provide teachers with real-time student learning data. This function simplifies the implementation of continuous progress monitoring which has been found to positively impact students' mathematics achievement. Information gathered through progress monitoring enables differentiated instruction that lets teachers modify teaching plans to match the needs of individual students. Together, progress monitoring with real-time data and differentiated instruction facilitated by immediate feedback can make a strong impact on enhancing students' learning experiences and outcomes.

References

Brosvic, G. M., Dihoff, R. E., Epstein, M. L., & Cook, M. L. (2006). Feedback facilitates the acquisition and retention of numerical fact series by elementary school students with mathematics learning disabilities. *The Psychological Record, 56*(1), 35-54. https://doi.org/10.1007/BF03395536

Chamberlin, M., & Power, R. (2010). The promise of differentiated instruction for enhancing the mathematical understandings of college students. *Teaching Mathematics and its Applications: An International Journal of the IMA, 29*(3), 113–139. https://doi.org/10.1093/teamat/hrq006

Faber, J., Luyten, J.W., & Visscher, A.J. (2017) The effects of a digital formative assessment tool on mathematics achievement and student motivation: Results of a randomized experiment. *Computers & Education, 106,* 83-96. https://doi.org/10.1016/j.compedu.2016.12.001

Foegen, A., Jiban, C., & Deno, S. (2007). Progress monitoring measures in mathematics: A review of the literature. *Journal of Special Education, 41*(2), 121-139. https://doi.org/10.1177/00224669070410020101

Foegen, A. (2008). Algebra progress monitoring and interventions for students with learning disabilities. *Learning Disability Quarterly, 31*(2), 65-78. https://doi.org/10.2307/20528818

Fuchs, L.S., Fuchs, D., Compton, D.L., Bryant, J.D., Hamlett, C.L., & Seethaler, P.M. (2007). Mathematics screening and progress monitoring at first grade: Implications for responsiveness to intervention. *Exceptional Children, 73*(3), 311-330. https://doi.org/10.1177/001440290707300303

Fuchs, L.S., Fuchs, D., & Hollenbeck, K.N. (2007). Extending responsiveness to intervention to mathematics at first and third grades. *Learning Disabilities Research and Practice,* 22(1), 13-24. https://doi.org/10.1111/j.1540-5826.2007.00227.x

Gersten, R., Chard, D.J., Jayanthi, M., Baker, S.K., Morphy, P., Flojo, J. (2009). Mathematics instruction for students with learning disabilities: A meta-analysis of instructional components. *Review of Educational Research, 79*(3), 1202-1242. https://doi.org/10.3102/0034654309334431

Grimes, K.J., & Stevens, D.D. (2009). Glass, bug, mud. *Phi Delta Kappan, 90*(9), 677-680.

Ismajli, H., & Imami-Morina, I. (2018). Differentiated instruction: Understanding and applying interactive strategies to meet the needs of all the students. *International Journal of Instruction, 11*(3), 207-218. https://doi.org/10.12973/iji.2018.11315a

Johnsen, S. (2003). Adapting instruction with heterogenous groups. *Gifted Child Today, 26*(3), 5-6. https://doi.org/10.1177/107621750302600302

Kickmeier-Rust, M.D., Hillemann, E., & Albert, D. (2014). Gamification and smart, competence-centered feedback: Promising experiences in the classroom. *International Journal of Serious Games, 1*(1). http://dx.doi.org/10.17083/ijsg.v1i1.7

Lou, Y., Abrami, P.C., Spence, J.C., Poulsen, C., Chambers, B., & d'Apollonia, S. (1996). Within-class grouping: A meta-analysis. *Review of Educational Research, 66*(4), 423-458. https://doi.org/10.3102/00346543066004423

McAdamis, S. (2001). Teachers tailor their instruction to meet a variety of student needs. *Journal of Staff Development, 22*(2), 1-5.

Nicolae, M. (2014). Teachers' beliefs as the differentiated instruction starting point: Research basis. *Procedia – Social and Behavioral Sciences, 128,* 426-431. https://doi.org/10.1016/j.sbspro.2014.03.182

Park, V., & Datnow, A. (2017). Ability grouping and differentiated instruction in an era of data-driven decision making. *American Journal of Education, 123*(2), 281-306. https://doi.org/10.1086/689930

Suprayogi, M.N., Valcke, M., & Godwin, R. (2017). Teachers and their implementation of differentiated instruction in the classroom. *Teaching and Teacher Education, 67,* 291-301. http://dx.doi.org/10.1016/j.tate.2017.06.020

Tieso, C. (2005). The effects of grouping practices and curricular adjustments on achievement. *Journal for the Education of the Gifted, 29*(1), 60-89. https://doi.org/10.1177/016235320502900104

Tomlinson, C.A., Brighton, C., Hertberg, H., Callahan, C.M., Moon, T.R., Brimijoin, K., Conover, L.A., Reynolds, T. (2003). Differentiated instruction in response to student readiness, interest, and learning profile in academically diverse classrooms: A review of literature. *Journal for the Education of the Gifted, 27*(2/3), 119-145. https://doi.org/10.1177/016235320302700203

Vygotsky, L. (1978). Interaction between learning and development. In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in society: The development of higher psychological processes* (pp. 79-91). Cambridge, MA: Harvard University Press.

Ysseldyke, J., & Bolt, D.M. (2007). Effect of technology-enhanced continuous progress monitoring on math achievement. *School Psychology Review, 36*(3), 453-467.

Ysseldyke, J., & Tardrew, S. (2007). Use of a progress monitoring system to enable teachers to differentiate mathematics instruction. *Journal of Applied School Psychology, 24*(1), 1-28. https://doi.org/10.1300/J370v24n01_01

Ysseldyke, J., Tardrew, S., Betts, J., Thill, T., & Hannigan, E. (2004). Use of an instructional management system to enhance math instruction of gifted and talented students. *Journal for the Education of the Gifted, 27*(4), 293-310. https://doi.org/10.4219/jeg-2004-319

Zhang, M., Trussell, R.P., Gallegos, B., Asam, R.R. (2015). Using math apps for improving student learning: An exploratory study in an inclusive fourth grade classroom. *TechTrends: Linking Research and Practice to Improve Learning, 59*(2), 32-39. http://dx.doi.org/10.1007/s11528-015-0837-y