How is classroom use of TI-Nspire™ and the TI-Nspire™ Navigator™ System enhancing pupil engagement, collaboration and learning?

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Research on teachers' use of TI-Nspire in mathematics and science classrooms shows that the unique capabilities of this new generation of handheld device help teachers engage learners in exploration, focus on conceptual understanding, and deepen learners' work with mathematical and scientific models. In addition, research suggests that integration of the TI-Nspire Navigator System will further enhance classroom collaboration and formative assessment.

Unique New Capabilities of TI-Nspire

The TI-Nspire platform includes a handheld device which builds upon features present in previous graphics calculators and adds significant new capabilities. Research has consistently shown that *multiple representations* increase learners' conceptual understanding of mathematics. TI-Nspire builds on this principle by integrating and linking high quality representations of graphs, geometry, algebraic expressions, data tables and text. Further, TI-Nspire allows teachers and learners to select and drag variables in representations, increasing interactivity and enhancing learner exploration.

The use of *documents* to structure and store learner work is another significant new capability. While teachers might worry that learners would find these new capabilities more difficult to use, research reports indicate that learners rapidly master the user interface, which parallels familiar computer interface features (Clark-Wilson, 2008; Aldon, 2008; Gantz, 2008). This research brief examines how these new capabilities are enabling teachers to change classroom practices. In addition, we discuss how the forthcoming inclusion of TI-Nspire Navigator's *communication* capabilities may accentuate learner engagement, classroom collaboration and assessment for learning.

Focusing on Concepts via Multiple Representations

Research reports on teachers' classroom lessons reveal that the enhanced multiple representations in TI-Nspire are bringing the benefits of multiple representations to a wider range of mathematical topics. Graphing equations and data representations are used often, however, other researchers designed and observed learners using geometry and spreadsheet features. A teacher in the UK felt that the use of TI-Nspire's geometry space enabled learners to develop a more intuitive understanding (less algorithmic) approach to angle bisectors. In a second UK classroom, learners were able to explore two circle theorems in depth because of TI-Nspire capabilities and the learners' familiarity with the tool. The teacher asked the class to investigate whether "opposite angles in a cyclic quadrilateral make 180 and angles in the same segment are equal." Learners created cases by moving the vertices of the circumscribed quadrilateral in the Geometry window and recording angle variables in the Spreadsheet window.

This exploration was memorable for teachers and learners: it was "beneficial to generate lots of different examples quickly" (Clark-Wilson, 2008). In another small study, sixteen pupils were divided into two groups, both of whom went on a trip to study a river system. One group used TI-Nspire to collect and "observe data graphically visualize data, while the other group used paper and pencil. Researchers found some promising gains in learning and reported that learners who used TI-Nspire formed more conceptual connections (O'Mahoney, Baer & Quynn, 2008). Across these uses, teachers and research report findings that are consistent with the established research showed that use of multiple representations can increase learners' conceptual understanding.

Engaging Explorations via to Select and Drag (also commonly called "dragging") enables learners to explore mathematical and scientific models interactively. The research literature shows that interactive exploration of models increases engagement, encourages learners to take responsibility for their own learning, and develops their understanding (Clark-Wilson, 2008; Aldon, et. al, 2008). Researchers examining classroom use of TI-Nspire find that teachers readily apply this new capability. For example, a teacher in the UK set her class the task of exploring π using the Geometry and Spreadsheet windows side by side. In one window, learners constructed a circle and then measured its circumference and

diameter. In the adjacent window, they set these measurements as variables in a table. Then, they observed the table as they changed the size of the circle. In some cases, however, learners had not constructed the diameter of the circle, but simply a disconnected line segment. As soon as they changed the size of the circle and observing the table, they realised their error. The teacher reported that learners gained awareness of the algebraic relationship between circumference and diameter of a circle.

Another teacher in the UK designed an activity that illustrated one of the ways in which TI-Nspire enables pupils to learn in new ways. Learners generated two linear graphs intersecting at the y-intercept by typing in two equations in the Graphs and Geometry window. The teacher then asked them to rotate one of the lines until the angle created at the intersection measured 90 degrees. Having the precision of angle measurement guaranteed by the calculator, learners could conjecture about the geometric and algebraic patterns they saw. Established research shows that exploring invariant relationships via dragging is a powerful cognitive strategy for developing problem solving skills (Goldenberg and Cuoco, 1998; Healy, 1999).

Using Documents to Deepen Learners' Mathematical Work

In contrast to repetitive procedure keystroke required by older technologies, documents enable teachers to set-up mathematical investigations in advance, saving precious classroom time. Research reports on teachers' classroom lessons with TI-Nspire show teachers are using documents to prepare thoughtful mathematical activities. The eCoLab team developed cross-referenced paper and TI-Nspire documents (pupil sheet – tns file) for each lesson. And, in the UK, teachers reported developing activities for topics covered in upper secondary classes because they felt TI-Nspire provided learners with the necessary scaffolds to access more advanced mathematics. In addition, documents are enabling teachers to focus more on the mathematics and less on the step-by-step setup procedures that were previously necessary for the older graphics calculator technology. In particular, teachers in a UK study felt that the lessons they had developed using TI-Nspire helped their learners make and test conjectures by allowing them to explore and manipulate mathematical objects.

Collaboration and Formative Assessment

Teachers using TI-Nspire are already reporting that documents increase learner collaboration, because learners can more readily share work, and that documents support formative assessment by enabling them to see what learners are doing. The forthcoming integration of the TI-Nspire Navigator System should further empower these classroom practices (Arzarello, 2008). A lesson enacted by teachers participating in the CROME project in France illustrates this potential. A CROME teacher posed the following problem: "Where ABC is an isosceles triangle for A, such that AB=AC= 10 cm, what is the area of the triangle?" Eight teams of learners computed the area for 5 values of BC (the base of the triangle) each. Learners expected a proportional relationship between length and area, and were surprised to see a curve cloud form as they shared their results in Activity Centre.

Learners offered varying explanations for this surprising (to them) result: some verbally explained that the triangle's area was initially small, grew, and then started to shrink. Others used gestures and numerical explanations for the curve. Collaborating on a shared space enabled these learners to gain access to deep mathematics and address a misconception regarding the functional relationship between the base of a triangle and its area. How learners reacted to the shared display was also a way for the teacher to gauge her pupils' understanding and for them to rethink their initial expectations. The TI-Nspire Navigator System will allow the teacher to view many learners' screens simultaneously and to make any learner a "live presenter" who can project the screen of their handheld device to the whole classroom. The popular Quick Poll feature also enables teachers to gain an instant overview of their learners' understanding and research has shown benefits for learning when classroom networks are used to enhance feedback

among the teacher and class (Roschelle, Penuel and Abrahamson, 2004). These capabilities should further enhance classroom sharing and assessment. In addition, TI-Nspire Navigator facilitates transfer of documents among the teacher and learners.

Conclusion: Transformative Potential

Before graphing was introduced to calculators, calculators served mainly as a means to reduce time spent on repetitive calculation and thus increase time spent on higher order mathematics. The introduction of the graphics calculator twenty years ago transformed mathematics classrooms because the speed and accuracy of graphs that are generated provides opportunities for increased conceptual understanding. TI-Nspire not only enhances graphing, but also integrates dynamic geometry with graphing, adds additional representations, increases interactivity via grab-and-move, provides documents to deepen learner work and supports more classroom collaboration and formative assessment. The transformative potential of TI-Nspire Navigator capabilities can be realised in the classroom when teachers use these capabilities to increase learner engagement, support learner exploration, focus on conceptual understanding, deepen learners' work with mathematical and scientific models, encourage collaboration and realise formative assessment.

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