Some Issues for Research and Instructional Design with TI-Nspire

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In these early days of the development and initial implementation of TI-Nspire, there exists some real overlap between issues of research design and those of instructional design: like all tools, *TI-Nspire* will not be used in a vacuum, and its effectiveness or otherwise for teaching and learning lies at least as much with the curricular context in which this use occurs as with the functionality and characteristics of the tool itself. In particular, the effective design of the *TI-Nspire* documents and plans for learning which accompany any planned learning intervention will be of critical importance.

To this end, there is value at this point in briefly considering broader characteristics of mathematical software and tool use, and clearly identifying the place of *TI-Nspire CAS* within this context. It is possible to identify three significant **dimensions** of mathematical tool use, each offering a potential continuum, along which we may place both our tool and the documents which might be developed to support its effective implementation:

1. **Goal or Purpose** – why are we using this tool? Is it to build conceptual understanding, with the primary focus upon the teaching and learning process, or to produce a clear and desired result in an efficient way, commonly linked to assessment and examination use?
2. **Function** – are we seeking to use this tool primarily for **representation** or for **manipulation** of mathematical objects or ideas? Or both?
3. **Locus of Control** – Do we design materials which carefully and thoroughly lead the user along well-defined paths to a specified end, or do we offer a more open and flexible learning experience?

These categories are not intended to be exhaustive nor exclusive, but rather to offer the basis for discussion and clarity of purpose as we plan for effective design of both instructional materials and research activities in this implementation stage of the use of *TI-Nspire*.

Purpose and Functionality

Available tools for mathematics have traditionally served two primary functions in the teaching and learning process: they tend to function either as tools for **representation** (graph plotters, tables of values) or tools for **manipulation** (calculators, spreadsheets, computer algebra systems (CAS)). The first is most often associated with building deeper and richer **conceptual understandings** through opportunities to view mathematical problems and situations in a variety of ways – to come from different angles and recognise both differences and commonalities. The second form tends to be associated more with **scaffolding of mathematical skills** – supporting students in their learning by taking care of the long and intricate calculations, which are usually associated with the messiness of the real world!

While these categories are far from mutually exclusive (consider, for example**, interactive geometry** – where does this tool best fit?), they offer a useful lens by which to view both software tools and types of problems, which may benefit from a technological approach. The unique and important place for *TI-Nspire CAS* lies in its ability to profoundly operate across these distinctions: it is, at once, fundamentally a tool for both multiple representations and dynamic manipulation of these representations. While other dominant mathematical tools may have limited features of both, each might be readily claimed for one camp or the other, as suggested in the table below.

Manipulation	**Representation**
Calculator (numbers)	Graph Plotter (graphical objects)
Spreadsheet (numbers)	Table of Values (numbers)
CAS (numbers and symbols)	Interactive Geometry (geometric objects)

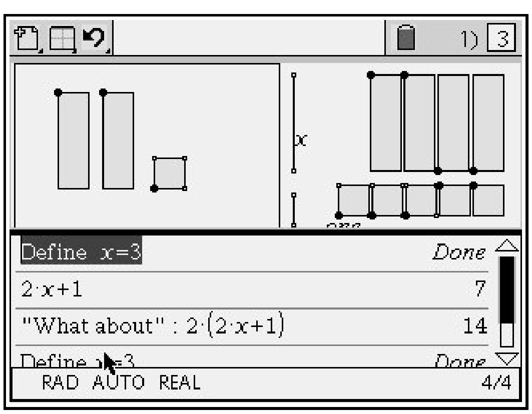
Limitations in previously available technologies have restricted the ability of these dominant tools to effectively operate across the two paradigms: while each may function in a limited and often trivial way in the other domain, they live primarily in one camp. An interesting exception to this is the ***SimCalc MathWorlds*** software, which clearly offers both powerful cross-representational facilities and the dynamic ability to manipulate these representations.

In the case of *TI-Nspire CAS*, it is the dynamic linking of representations that supports a powerful and unique blend of multiple representations, and immediate and effective tools by which these may be interactively and jointly transformed. While this is most clearly seen in the relationship between the *Graphs & Geometry* environment and the *Lists & Spreadsheet* tool, the definition of variables across the environments extends this shared functionality: changes to a linked variable within the symbolic environment of the *Calculator* will produce an immediate physical change to the object linked to that variable within the world of *Graphs & Geometry*.

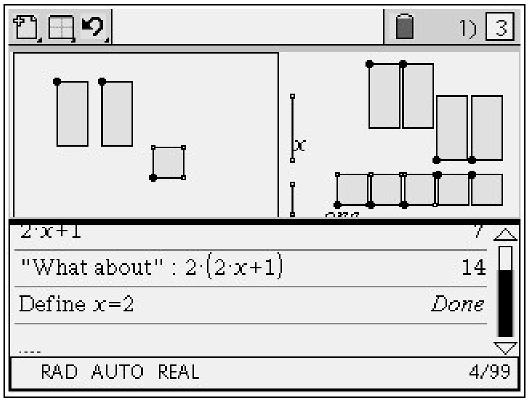
A powerful implication of this dynamic linking lies in the potential support of virtual manipulatives offered within the *TI-Nspire CAS* environment. The effectiveness of concrete manipulatives for building powerful algebraic understandings and skills is well supported by research and classroom practice. The limitations of such concrete models are twofold:

1. There is no direct link between the concrete and the symbolic, other than that drawn by the teacher, who needs to remind students that a units square represents 1, and the rectangle of unknown length may be presented by a pronumeral, such as “x”;
2. More significantly, the concrete models, once constructed, are static: “x” takes on a fixed value and so fails to adequately support the key notion of variable.

Within the dynamic environment of *TI-Nspire CAS*, the use of such static, concrete materials may be powerfully complemented by virtual shapes which are truly variable:



As with the concrete models, “1” shapes and “x” shapes may be used to construct algebraic expressions by dragging these onto a “stage”. Here we see the expression “2x + 1”. At the same time, a value for “x” is defined within the *Calculator*, and the expression is seen to have both a concrete representation, and an algebraic and numerical one – “2x + 1”, when “x = 3” is 7.



Redefining the symbolic value of “x”, however, immediately changes the visual “concrete” representation, powerfully linking the visual, algebraic and numerical aspects of the task, and strongly supporting the concept of “variable” as applied to the pronumeral.

The implications for both instructional and research design are clear – if *TI-Nspire* is to be used most effectively and to be showcased most powerfully, then it is the unique blend of manipulation and representation that should be at the forefront. In particular, opportunities must be sought to draw dynamic connections, not just between the graphical and numerical worlds of the device (since this has been well-established in previous technologies), but to clearly and convincingly link the *symbolic* with these other forms. While the algebraic structure of the spreadsheet readily invites such connections, it is likely to be dynamic linking between the algebraic and the geometrical environments of *TI-Nspire CAS* that will be most dramatic and most powerful from a teaching and learning perspective. Certainly, the facility of a geometric model to generate data which may be graphed and then used to verify student-developed algebraic models appears to offer a potentially new approach to the teaching of algebra across the secondary years – especially when supported by a transparent and easy-to-access CAS environment. (see Arnold, 2006a).

Designing Effective Instructional Sequences

Merrill (2006) identifies common principles in the various theories and models for instructional design, which he distils into a four-phase cycle of instruction:

1. Activation, in which students are directed to draw on previous learnings and knowledge relevant to the task at hand, which forms a foundation for new knowledge;
2. Demonstration, which involves active *portrayal* (rather than just telling) of the new knowledge, using specific and concrete examples applied to a particular situation;

3. Application involves more than just recounting; learners apply their new knowledge to complete whole tasks or solve entire problems; and
4. Integration, involving public demonstration of their learning and opportunities for learners to explore and use their new knowledge in new ways.

The backdrop for this cycle is a scaffolded problem solving environment, in which students are guided through appropriate tasks with direct instruction of components of the problem.

Adding an additional stage between 2 and 3 above in which learners are required to verbalise their new knowledge using their own words ("explicitation") would lead to a very close correlation with the instructional sequence offered by the van Hieles some twenty years ago (van Hiele, 1986), and the van Hiele requirement of the need to induce a "crisis of thinking" if deep learning is to occur remains relevant. (See, for example, http://four.fsphost.com/smarnold/PAGES/CS3.htm and http://four.fsphost.com/smarnold/ACU/variables.pdf)

Such models, however, offer clear guidelines on which effective instructional design may be based. These guidelines are further enhanced by work over the past decade which seeks to make explicit those principles of good teaching which are commonly recognised in research and practice ("authentic pedagogy" (Newman, 1995), "productive pedagogy" (Education Queensland, 2001) or "quality teaching" (New South Wales Department of Education and Training, 2003)). At very least, such models offer a language by which teachers and others involved in the educational process may discuss and make sense of what works and what does not in classrooms.

The three core domains of good teaching are immediately recognisable: the need for **Intellectual Quality**, for the creation of a **Quality Learning Environment**, and for that which is to be learned to be **Sigificant** to the learners. Each domain is populated by clear criteria and the framework offers a valuable tool for research and evaluation of instructional processes. Further detail may be found at http://four.fsphost.com/smarnold/integrate/pedagogy.htm. (Arnold, 2006b).

Bringing it all together

My interest in these matters is threefold: to develop appropriate and effective instructional materials supporting the use of TI-Nspire CAS, to support teachers in Australian Pilot Schools over the next twelve months, and to offer support for the gathering and dissemination of research data which documents our implementation process, and informs good practice in the future use of TI-Nspire.

As such, the issues discussed above are timely and relevant: we must be clear as to which of the capabilities and functionality of TI-Nspire we wish to promote and showcase (focusing strongly upon the dynamic linking capabilities across multiple representations), we must distinguish between the two primary uses of the tool – for learning and for assessment (while certainly related, they are yet quite distinct), and we should strive to build a model of instruction which not only supports the effective use of this powerful new tool, but explicitly directs teachers and students towards a model of learning which is positive and learner-centred, building deep understandings as well as flexible and transferable mathematical skills, and culminating in high levels of both competence and confidence in their mathematical learnings.

References

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APPENDIX: Response from Rob Foshay (Director of Research, Texas Instruments)

Steve,
This is an exciting paper! I expect it will generate some great thinking in Europe, and with our publisher partners. It obviously resonates very well with my thinking on the issue.

In case you haven't seen it, I'm attaching SRI's research basis paper. It includes the point about dynamic multiple representation that your paper addresses (though your discussion has much more depth). Underlying Jeremy's thinking is a concept of 5 instructional models for which TI-Nspire is particularly suited:

- Modeling
- Project-Based Learning
- Participatory Simulations
- Direct Instruction

And when the link to TI-Navigator is added:

- Differentiated Instruction

What's particularly important about the direction you're headed, and what's been guiding my thinking, is the idea that we need to think in terms of instructional models for particular teaching purposes as a way of designing instruction using TI-Nspire CAS+. One of the great points of significance here is the document-centric structure of the device, which creates for the first time the need for much more complete and sophisticated instructional designs, both to scaffold the student and to scaffold the instructor.

Also, let's think of these models as a framework for assessment as well as instruction. By capturing a series of documents, we can store the progression a student makes as he/she solves a problem. If we can figure out what the progression is telling us about the student's achievement, we'll have a significant advance.

Incidentally, I'm pleased that you find Merrill's "first principles" work useful. I've been a fan and user of this project since he first thought of it, One of the very few examples of disciplined cumulative knowledge building and synthesis in our field.