Frameworks for analysing the expertise that underpins successful integration of digital technologies into everyday teaching practice

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Overview of the full paper

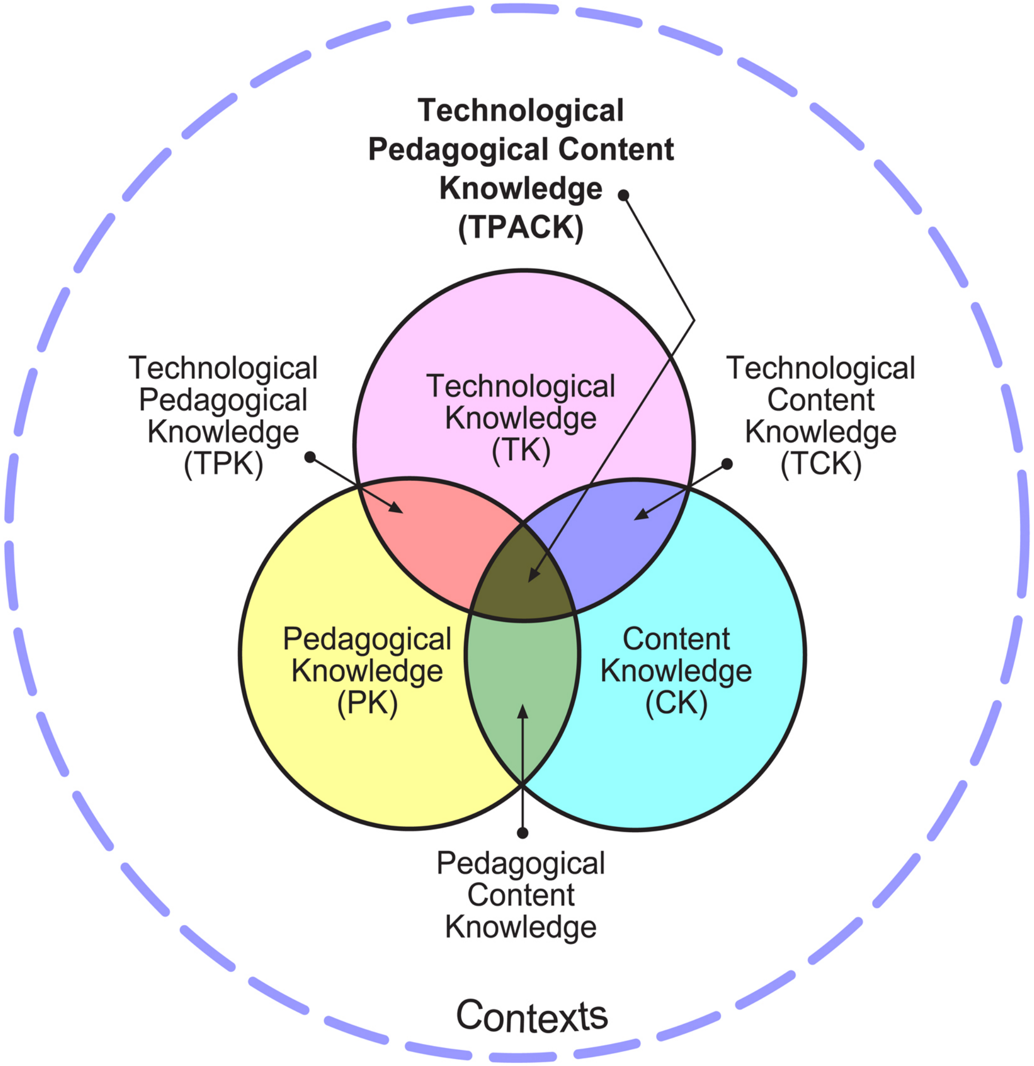
- Relevant teacher expertise is recognised as being crucial to successful integration of digital technologies into everyday teaching practice.
- This paper examines three frameworks for analysing such expertise:
  - the Technological, Pedagogical and Content Knowledge (TPACK) framework (Koehler & Mishra 2009);
  - the Instrumental Orchestration (IO) framework (Trouche 2005; Drijvers et al. 2010);
  - the Structuring Features of Classroom Practice (SFCP) framework (Ruthven 2009).
- For each framework, the paper considers a corresponding study of teacher use of digital technologies for algebraic graphing, a now well-established usage serving here as an exemplary reference situation.
- The paper concludes by discussing commonalities, complementarities and contrasts between the frameworks.

Main structure of this presentation

- Sketch of each framework in turn:
  - Overarching constructs and structure
  - Elaborated characterisation of elements
    - *Time does not permit attention in today's talk*
  - Supporting rationale and related critique
  - Practical operationalisation in illustrative study
- Comparing and contrasting frameworks
- Conclusions and recommendations

- Both the full paper and these presentation slides can be downloaded from http://www.educ.cam.ac.uk/people/staff/ruthven/

Overarching constructs and structure of TPACK



(Mishra & Koehler 2006; Koehler & Mishra 2009)

Component	Elaborated characterisation
TK	Knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video. Includes: • the skills required to operate particular technologies • knowledge of operating systems and computer hardware • ability to use standard sets of software tools such as word processors, spreadsheets, browsers, and e-mail • knowledge of how to install and remove peripheral devices, install and remove software programs, and create and archive documents
TCK	Knowledge about the manner in which technology and content are reciprocally related. Includes: • knowledge of how technologies afford particular representations and flexibility in navigating across them • knowledge of the manner in which the subject matter can be changed by the application of technology
TPK	Knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies. Includes: • understanding that a range of tools exists for a particular task • ability to choose a tool based on its fitness and strategies for using the tool's affordances • ability to apply pedagogical strategies for use of technologies
TPCK	Emergent form of knowledge that goes beyond all three components (content, pedagogy, and technology). Includes: • understanding of the representation of concepts using technologies • pedagogical techniques that use technologies in constructive ways to teach content • knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face • knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones

Supporting rationale and related critique of TPACK

- Extension of Shulman's PK–CK–PCK model to acknowledge T mediation:
  - Technologies which mediate established practice tend to be invisible, while new technologies have potential to disrupt such practice;
  - Interactions between technology, pedagogy and/or content produce knowledge "intersections" which TPACK seeks to highlight.
- Some underdeveloped aspects and inconsistencies in use:
  - Interpretation of "intersection" of knowledge domains could be sharpened: ranges from casual co-incidence to irreducible fusion;
  - Potential for more fine-grained discrimination between, for example:
    - Pedagogical strategies relating to development of student TCK;
    - Technological strategies supporting application of teacher PCK.
  - Differentiation between concrete knowledge of particular pedagogy or technology, as against more reflexive knowledge of alternatives.

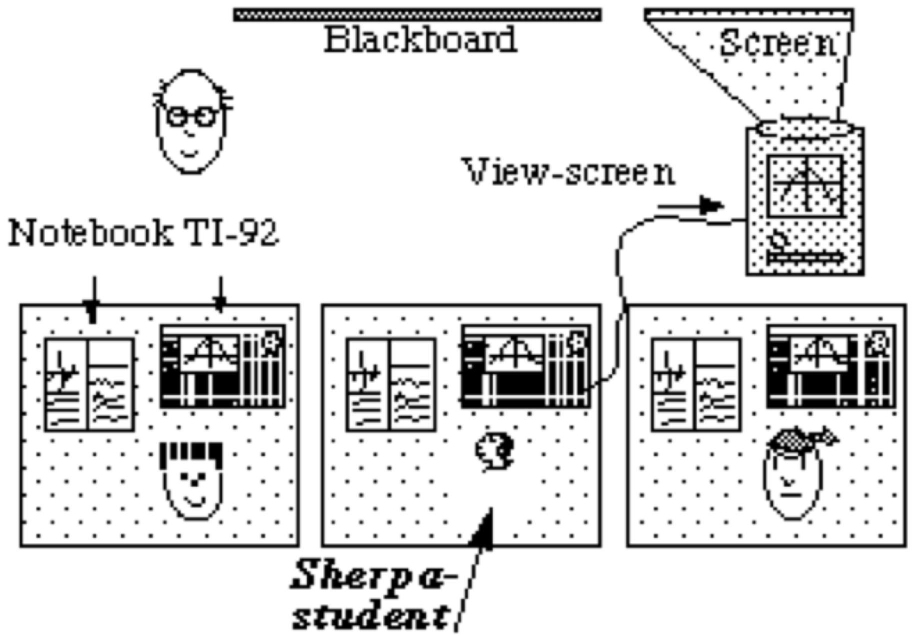
Illustrative study employing TPACK (Richardson 2009)

- In this study of middle-school teachers participating in a professional development programme, the TPACK framework was used to break down and classify observational records of interactions and discussions between participants and entries extracted from their professional journals.
- The study reports that it was not straightforward to demarcate categories which tended to acquire narrower operationalisations directly related to particular features of the professional development programme.
- In particular, use of the TPACK framework to analyse naturally occurring teacher discourse often foundered because such utterances provided insufficient evidence to draw confident inferences and make clear discriminations about the knowledge in play or under development.
- Here it appears that TPACK was more valuable as a holistic construct inspiring the professional development course than as a research tool for analysing the process or product of knowledge construction.

Overarching constructs and structure of IO

- Didactical configuration + Exploitation modes
- May operate at the level of:
  - the artifact itself;
  - a set of instruments;
  - the relationship a subject maintains with an instrument.
- e.g. A *sherpa* student operates a calculator projected to the whole class under the guidance of, and subject to checking and questioning by, the teacher.

(Trouche 2009)



Orchestration example	Didactical configuration	Exploitation modes
Customised calculator	Classroom calculators are "fitted out" with a guide affording three levels of study of the limit concept. These are designed to support the shift from a kinetic concept of limit to an approximative concept	Guide can be available always or only during a specific teaching phase. Students can use guide freely when available, or be constrained to follow the order of the levels. Components can be fixed, or updated in response to classroom lessons. Recording of steps of instrumented work, can be required, or not.
Sherpa student	A *sherpa* student operates a calculator projected to the whole class under the guidance of, and subject to checking and questioning by, the teacher, intended to provide a common reference in addressing the collective instrumental genesis of the class.	Calculators and projector off: work with pencil and paper only. Calculators and projector on: work strictly guided by the sherpa-student under the supervision of the teacher, with other students supposed to replicate the projected display on their own calculator. Calculators and projector on: students work freely but are able to view the work of sherpa-student Calculators on and projector off: students work without being able to view work of sherpa-student
Paired practicals	Each student is equipped with calculator and pencil and paper. Students work in pairs to solve an assigned problem. Each pair then has to explain and justify their reasoning and results, noting observations and dead-ends in a written research report.	Students can be free, or not, to form pairs. Students can be free, or not, to choose which one will write the research report. The teacher can offer help to students during the practical, or only at the end of it, or a week after. Written research reports can be handed in at the end of practical, or a week later. After reading students' research reports, the teacher can give a problem solution, or only give pointers to new strategies for students to pursue.
Mirror observations	Students work in pairs. While one pair tackles a mathematical task, another pair, guided by an observation protocol, notes the actions carried out for later discussion and reflection.	May be used only exceptionally, or be a regular tool for regulation of students' tool-using activity. May fix, or not, the role of each student in the working pair (e.g. one can be in charge of the calculator, the other in charge of the report). Protocol can be modified according to the type of mathematical problem set.

Supporting rationale and related critique of IO

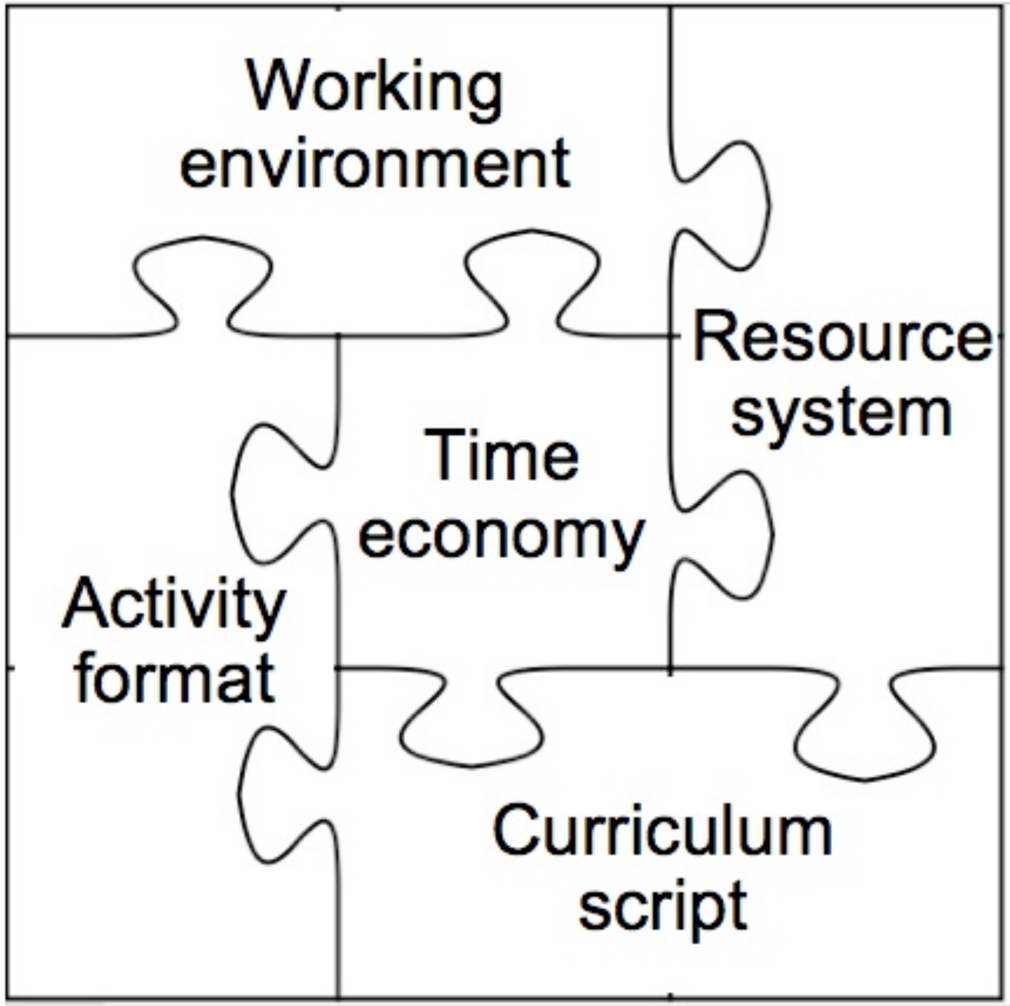
- Extension of Rabardel's instrumental approach from cognitive ergonomics:
  - Conversion of crude artefact into functional instrument involves co-evolution of naïve operator to become proficient user through a process of "instrumental genesis" of schemes for usage and action;
  - Through "instrumental orchestration" the teacher seeks to manage what could potentially be very disparate instrumental geneses on the part of individual students so as to ensure that technico-mathematical development within a class follows a more collective path.
- Construct needs tightening both at theoretical and operational levels:
  - First example ('Customised calculator') involves adaptation of the tool itself, whereas the other three all attend to the organisation of activity and assignment of roles associated with use of the tool.
  - Equally, the first example depends much more explicitly on analysis of what might be described as a specific "instrumental trajectory" of the class towards intended technico-mathematical learning outcomes, whereas this dimension is unelaborated in the latter three.

Illustrative study employing IO (Drijvers et al 2010)

- Through lesson observations supplemented by teacher questionnaire and interviews, this study developed a typology of the forms of organisation of whole-class activity employed by teachers using a function microworld.
- It modified the construct of “instrumental orchestration” in several ways:
  - Focusing it as a prototype of classroom organisation and social roles;
  - Treating each combination of a particular “didactical configuration” with more specific “exploitation modes” as a distinct “orchestration”;
  - Emphasising “the way the teacher decides to exploit a didactical configuration for the benefit of his or her didactical intentions”;
  - Adding a component of “didactical performance” to acknowledge the way in which plans are elaborated and adapted in action.
- Developing this typology helped to identify overall patterns in classroom activity, and to pinpoint differences between the profiles of teachers, and between teacher enactments of the same sequence with different classes.
- These orchestration types represent a collective system of professional expertise for organising classroom lessons using digital technologies.

Orchestration type	Didactical intention	Didactical configuration	Exploitation modes
Technical-demo	Demonstration by the teacher of techniques for using the tool	Provision to project DME Classroom arrangement allowing students to view the projected screen	Teacher employs new situation or their own solution or earlier student work as a point of departure
Explain-the-screen	Explanation by the teacher going beyond technique, involving mathematical content	Provision to project DME Classroom arrangement allowing students to view the projected screen	Teacher employs new situation or their own solution or earlier student work as a point of departure
Link-screen-board	Instruction by the teacher relating the representations of mathematics in different media	Provision to project DME Classroom arrangement allowing students to view both the projected screen and the board	Teacher employs new situation or their own solution or earlier student work as a point of departure
Discuss-the-screen	Discussion between teacher and students about what is happening on the screen	Provision to project DME and preferably to access student work Classroom arrangement allowing students to view the projected screen and favouring discussion	Teacher employs new situation or their own solution or earlier student work as a point of departure
Spot-and-show	Discussion between teacher and students in which student reasoning is brought to the fore through deliberate use of carefully chosen student work	Access to student work in the DME during lesson preparation Provision to project DME Classroom arrangement allowing students to view the projected screen	Teacher chooses earlier student work in advance of the lesson as a point of departure for the student to explain their reasoning, or for other students to give reactions, or for the teacher to provide feedback
Sherpa-at-work	Activity in which a sherpa-student uses the technology to present his or her work, or to carry out actions that the teacher requests	Provision to project DME Classroom arrangement enabling sherpa to use the projected tool and other students to view the projected screen and follow contributions of sherpa and teacher	Teacher has work presented or explained by the sherpa-student, or poses questions to the sherpa-student and asks them to carry out specific actions in the technological environment

Overarching constructs and structure of SFCP



(Ruthven 2009)

Structuring feature	Defining characterisation	Examples of associated craft knowledge related to incorporation of digital technologies
Working environment	Physical surroundings where lessons take place, general technical infrastructure available, layout of facilities, and associated organisation of people, tools and materials	Organising, displaying and annotating materials Capturing or converting student productions into suitable digital form Organising and managing student access to, and use of, equipment and other tools and materials Managing new types of transition between lesson stages (including movement of students)
Resource system	Collection of didactical tools and materials in use, and coordination of use towards subject activity and curricular goals	Establishing appropriate techniques and norms for use of new tools to support subject activity Managing the double instrumentation in which old technologies remain in use alongside new Coordinating the use and interpretation of tools
Activity structure	Templates for classroom action and interaction which frame the contributions of teacher and students to particular types of lesson segment	Employing activity templates organised around predict-test-explain sequences to capitalise on the availability of rapid feedback Establishing new structures of interaction involving students, teacher and machine and the appropriate (re)specifications of role
Curriculum script	Loosely ordered model of goals, resources, actions and expectancies for teaching a curricular topic including likely difficulties and alternative paths	Choosing or devising curricular tasks that exploit new tools, and developing ways of staging such tasks and managing patterns of student response Recognising and responding to ways in which technologies may help/hinder specific processes and objectives involved in learning a topic
Time economy	Frame within which the time available for class activity is managed so as to convert it into "didactic time" measured in terms of the advance of knowledge	Managing modes of use of tools so as to reduce the "time cost" of investment in student learning to use them or to increase the "rate of return" Fine-tuning working environment, resource system, activity structure and curriculum script to optimise the didactic return on time investment

Supporting rationale and related critique of SFCP

- Devised by linking a range of constructs from earlier studies of classroom organisation and interaction and of teacher craft knowledge and thinking:
  - Central concern is with how material-cultural factors interact with functional organisation of technology use and teaching expertise;
  - The framework identifies structuring features of classroom practice which shape the ways in which teachers integrate new technologies.
- Limitations linked to early stage of development have been noted:
  - The differing provenance of the five central constructs raises some important issues of theoretical coherence and conceptual integration;
  - Studies are required in which data collection (rather than just *post hoc* data analysis) is guided by the framework, so that it can be subjected to fuller testing and corresponding elaboration and refinement;
  - To adequately address issues of professional knowledge and learning, such studies need to be longitudinal as well as cross-sectional, and to focus on teachers' work outside as well as inside the classroom.

Illustrative study employing SFCP (Ruthven et al. 2009)

- Through lesson observations supplemented by post-lesson interviews with teachers, this study examined the adaptation of teaching practices and development of craft knowledge associated with teachers' use of graphing software to teach about algebraic forms at lower-secondary level.
- In terms of *resource system*, teachers had developed strategies to introduce students to core techniques with graphing software and allow them to explore and share further, as well as built their own expertise in the forms of technico-mathematical guidance that students might require.
- In terms of *activity structure*, a distinctive type of activity format was emerging for student work on a new type of 'target practice' task which capitalised on the interactivity of the software to centre investigative activity around a process of trial and improvement of posited solutions.
- Teachers had woven these preceding elements into their *curriculum script* for the topic, along with a repertoire of strategies concerned with prompting strategic action and supporting mathematical interpretation.
- Changes in *time economy* had required corresponding adaptation of curriculum sequences on this topic and recalibration of their timing.

Comparing and contrasting frameworks

- The TPACK framework focuses on epistemological demarcation between different classes of knowledge relevant to teaching, whereas the SFCP framework focuses on the functional organisation of teaching expertise.
- Instrumental genesis – in IO terms – focuses on the co-evolution of technological and content knowledge, placing – in TPACK terms – the growth of student TCK at its core, and emphasising the pedagogical knowledge (P–TCK rather than T–PCK?) required to manage this growth. But instrumental orchestration (in Trouche's later types and Drijvers et al's adaptation and extension) seems to take the form of a more generic TPK.
- The types of IO identified by Drijvers et al. all correspond – in the terms of SFCP – to specific activity formats that exploit a particular resource (sub) system (and its underlying working environment). However, Trouche's first IO corresponds to customising part of the resource system so as to support an innovative pathway within the curriculum script.

Conclusions and recommendations

- Each of these frameworks provides:
  - An overarching set of constructs reflecting a particular perspective on the phenomenon of technology integration in subject teaching;
  - A tentative listing of more concrete elements/examples necessary to support operational use of these constructs as analytic tools.
- This points to a crucial need for more systematic investigation of technology integration into subject teaching in ways that link these levels:
  - More intensive elaboration at the concrete level could serve to better operationalise existing frameworks and synthesise them;
    - c.f. Drijvers' paper in which IO is crossed with TPACK, in forthcoming symposium on *Resourcing Mathematics Teacher Work and Knowledge,* Tue Apr 30 2:00–3:30, Hilton Union Square Sixth Level-Tower 3 Lombard
  - A synthesising framework would provide a more powerful overarching system of constructs capable of systematically organising a much richer and fuller inventory of the kinds of more concrete elements that these three frameworks have started to identify.