My research focuses on computer aided assessment and computer based learning of mathematics at the higher education level. I have focused on the use of computer algebra as part of computer aided assessment to support a variety of tasks. The application of CAS to support an online assessment system is quite different from the normal roles to which a CAS is traditionally put, which include a reduction in the computational load, automation of graphical representations, and the ability to perform rapid re-calculation to facilitate explorations.

As an illustration, consider the situation in which a student enters his or her response to a mathematical question into a CAA system. The system then uses a CAS to subtract the student's response from the teacher's response and to simplify the resulting expression algebraically. If the result is zero an algebraic equivalence between the student's answer and the teacher's answer has been established. The system then takes appropriate action, such as providing feedback and assigning a mark.

Note that the CAA system evaluates the student's answer which contains mathematical content, rather a selection from a list of teacher provided answers, such as in multiple choice or multiple response questions. This allows a assessment in situations where the MCQ and similar formats are not valid.

Establishing algebraic equivalence is only a prototype test in which we establish a certain property of the student's answer. Other more sophisticated properties can be established with the support of a CAS. For example, it is possible to assess questions such as the following. "Give an example of a function which is continuous but not differentiable at x=1, and which has a stationary point through the coordinates (3,1)". Here the response of the student can be tested for the individual properties and outcomes assigned. Such questions require the student to consider carefully what properties are required and then construct an example of their own to satisfy them.

Systems in which the processing of student's answers is supported by computer algebra has gradually gained ground in higher education over the last five years. Perhaps the first system to make CAS a central feature was the AiM system. This system operates using Maple, as does the Wallis system. Other CAA implementations have access to a different CAS, such as, which uses Axiom. The STACK system (http://www.stack.bham.ac.uk), which I designed and implemented, uses the CAS Maxima. There are also systems, which use Derive in a similar way.

There are essentially two groups of learners which need serious consideration. The first is for students: who are the traditional focus of educational research. The second is for colleagues who need to learn how to effectively use increasingly complex and
sophisticated CAA tools. The CPD needs of staff learning CAA are often not addressed explicitly by educators.

In this new setting the student--machine interface takes on a new importance. The student must now communicate their answer unambiguously to the computer. Computer algebra systems already have a linear syntax, and one approach is to adopt this for students. A graphical input tool or pen-based entry system (could also be used.

Traditionally in an interactive CAS session the student can edit and alter their input at will, correcting inevitable mistakes and where needed consulting staff or online help files. When designing a computer aided assessment system the stakes are higher: the student is being evaluated on their input. We certainly do not wish to mix an evaluation of their ability to express themselves using the correct syntax with their ability to actually solve the problem in hand. If so, the user risks being penalized on a technicality which has important implications for high stakes assessment. It is a fundamental tenet of psychological measurement that in any test situation one should maximize construct-relevance and minimize construct irrelevant variance. Hence, in designing for the interactions of students with CAA, what mathematical symbols mean to students, the way they use them and how they are interpreted by the machine is of fundamental importance.

**Important References:**