The transcript below illustrates a typical conversation in which students drew upon their experience with hardware while designing scale mechanisms.

VIVIAN: If this is, em, you know, like one of those farmer toys where you pull the string and it rolls back, maybe it's something like that where it's maybe a spring-loaded coil or a spring-loaded, em, disk with a thing attached to it.
VIVIAN: Did you ever watch a music box unravel? Like, you know, these kinds of springs like this, so if you squish it, it causes some kind of rotation.
JUAN: Mmmm right.
VIVIAN: And if you have rotation in one orientation you can usually translate in one orientation you can usually translate it into another.
JUAN: Yeah, you're right. I guess I have watched those too.
VIVIAN: Yeah exactly right . . . right.

Figure 4.6 shows a design developed by one student who searched his bag to find a ball-point pen or biro, when he noticed the motion of the scale was similar to that of a biro. He proceeded to dissect the biro in order to learn how it worked. He sketched the mechanism. He then sketched a design for the scale that built heavily on the biro's deployment-retraction mechanism.

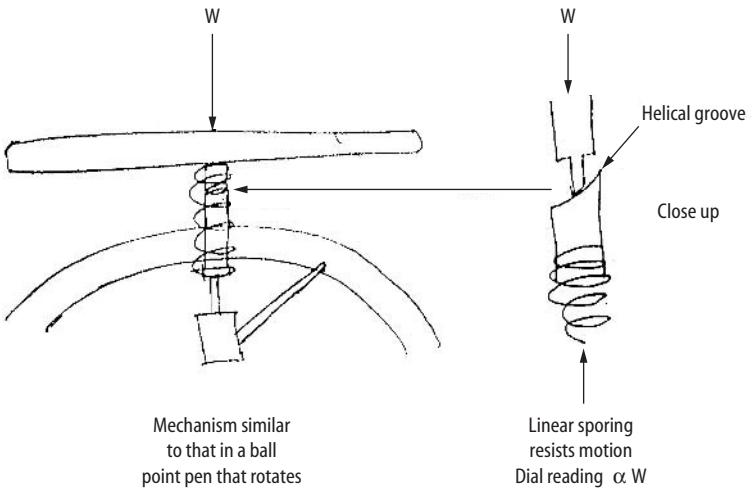
These observations provide evidence that one way in which we think about and remember ways of implementing abstract functions, such as linear to rotary motion, is through our experience of artefacts – that is, if we try to design a catch mechanism, one way to go about it is to seek inspiration from all sorts of things that we open and close: umbrellas, CD holders, doors, egg cartons, briefcases, laptop computers, VCRs, etc. Novice designers do not store a library of different kinds of abstract catch mechanisms where they remember the particular geometric configurations of each catch; whether or not experts do so is an open question. Rather, novices recall experiences of products that need catches to keep them open or shut. And they recall the catch in its particular context of use, remembering the feel of opening it.

Based on these observations we can draw some conclusions about the internal representations used by designers. At least, we can state how these memories are manifested as external representations on recall. Designers express what they remember about devices by:

1. Recalling the experience of using a device, noting the device behaviour, particularly referencing actions and movements.
2. Naming and drawing standard machine elements.
3. Gesturing and drawing geometric configurations of previously experienced devices.

## Hardware thinking props

The second notable behaviour in the scale's conceptual design was the opportunistic seeking out and use of miscellaneous hardware to think with and gesture with (ready-made representations). In a barren design environment consisting of a classroom full of chairs, tables, sketch pad and pens, students sought out inspiration from: gesturing with pens; pulling and twisting a rubber band that happened to be lying on a table; and dissecting a ball-point




*Above:* A sketch taken from a student's sketch pad showing a design based on a biro (ballpoint pen) deploy-retract mechanism.
*Below:* A design conversation in which students build on the design sketched above.

Raul: [Looks in bag for a biro (ballpoint pen).] I've had the experience of taking apart a biro. I reckon it could be like a biro.
Mark: [Laughs] You reckon it could be like a biro?
Raul: It could be when you think about it.
[Examines biro and sketches for a while.]
Mark: What's there?
Raul: That's a close-up of that area there (see sketch above). It's like a pen – you know, how one of these pens as you're pushing it down that's got those tags in it and they make this go around, like when you put that in it pushes round and so that rotates it should do that and I was thinking like it could be like that with these grooves and, if instead of having gaps, you have like one spiral groove there, you could press this down and this is spring-loaded at the bottom for resistance and so, however much you push this down, this rotates an amount (inaudible).
Mark: That' s really cool Raul.
Liam: Novel, novel.
Mark: I dig that, that's good.
Mark: So is it meant to be keeping on going round so that.
Raul: Yeah, enough so that.
Mark: I suppose you can only go around once. Well, no, you could have it going around more if you had this pushing down from the outside.
Raul: If you had it winding in a taper or something.
Raul: Like if your helical groove thing was like and you had your tongue thing sitting out here on the groove like a screw thread that screws it around.

**Figure 4.6** Hardware as a starting point and memory device – designers build on experience with existing hardware devices.

pen dug out from a student's rucksack. Of the incidental hardware in the room, students adopted hardware tools that were easily accessible and that had affordances or convenient properties. Pens were long and slender like linkage links and rubber bands were stretchy like springs. This is not to say that the properties were optimal or entirely suitable, or that it would be possible to specify a priori what would be suitable. The hardware was simply conveniently available and had some attribute that made it helpful for students to gesture and think with. This opportunistic behaviour has been observed in