Materials Innovation in Acoustic Guitars: Challenging the Tonal Superiority of Wood

Owain Pedgley and Eddie Norman

The earliest makers of stringed musical instruments will no doubt have reviewed available materials and chosen wood because little else existed that could be fashioned into a credible instrument. Today, the acoustic guitar can be regarded as “archetypal” [1], manufactured from wood and possessing attributes that have become standardized over time. However, makers of non-wood stringed instruments usually challenge the idea that past masters’ achievements with wood (e.g. by Antonio de Torres with the classical guitar or Antonio Stradivari with the violin) represent an insurmountable “sonic pinnacle,” instead suggesting that historically these makers constructed instruments that were the best that could be achieved with traditional materials [2]. The ambition of makers of non-wood acoustic guitars is usually to realize a materials-based innovation [3,4] in which the shift to alternative materials opens new design and manufacturing routes or advantages to musicians.

Although there currently exist many examples of acoustic guitars manufactured from non-woods, for example by Ovation, Composite Acoustics, RainSong, Garrison, Blackbird and Emerald, these instruments are favored only by a niche of musicians. Musical instruments make up a generally conservative product sector, in which tradition and conformity of wood are held in a high regard. In contrast, other product sectors, for example sports equipment, have witnessed remarkable developments in new materials use [5].

A general skepticism about the use of alternative materials for acoustic guitars is readily detected among players and retailers. The belief persists that the use of specific tonewoods, such as mahogany, rosewood and close-grained spruce, is essential to creating an instrument with high-quality sound, playability and appearance. On the other hand, even though the sonic reputation of plastics as an instrument construction material is not high [6], guitar makers usually accept that some alternative materials to wood can be viable, although they rarely possess personal experience of working with alternative materials. High-profile market failures, such as Mario Maccaferri’s range of plastic guitars, have compounded the negative impression of plastic as an instrument-building material. Furthermore, the idea of a “marriage” between plastics and musical instruments can conjure negativity in renowned players and designers, as the following quotes show. This is partly because plastics continue to be associated with artifacts of low value, even though this is a very unfair generalization given their diversity and widespread product use.

Nigel Kennedy: I have got these amazing violins made in Birmingham by David Bruce Johnson . . . great electric violins . . . the first ones that don’t sound too plastic and trebly [7].

Robert Moog: Digital instruments are fine for a lot of things, like sample playback, programmability, precision and relatively low price. But sound wise, I think we’re talking about the difference between, say, a plastic guitar and a wooden guitar [8].

Peter Dormer: the very sound of plastic is dull: it does not resonate or ring out or ping, but thuds [9].

It is notable that such comments are still made, despite everyday experiences such as knowledge of the acoustic sensitivity of expanded polystyrene packaging or the common use of plastics in recorders and other wind instruments. One reason that musicians tend to attach romanticism to the use of wood in musical instruments is that the material originated from a living tree, and the “soul” of that tree is transferred to the instrument and therefore into the music that is played. Thus, there can exist an emotional reluctance, rather than a logical response or informed decision, to embrace acoustic guitars constructed from materials other than wood.

Despite the general reluctance of players to accept new designs or approaches, the pursuit of materials innovation in acoustic guitars has historical precedents involving relationships forged among a small number of high profile makers and players. For example, Antonio de Torres was associated with Francisco Tárrega during the creation of his classical guitars, and Mario Maccaferri was associated with Django Reinhardt for the “gypsy jazz” guitar. In the modern era, U.S. luthier Greg Smallman has worked with guitarist John Williams to champion the drive for improvements in the sound and consistency of the acoustic guitar, for example, through the introduction of carbon fiber struts to brace the soundboard.
Irrespective of the particular materials used, each of these makers responded to requirements associated with the particular musical styles of the players, as well as more technically straightforward matters such as the need for increased volume or stability under changing environmental conditions.

The instruments introduced in this article are radical in that they have soundboards and strutting fabricated not from spruce or cedar but from foamed polycarbonate, a high-performance synthetic thermoplastic. They stem from a project to develop acoustic guitars with thermoplastic components, which could be precision molded in mass production and would offer considerable opportunities for new and attractive designs [10]. The acoustic technology for the guitars was established between 1995 and 1999 as part of a Ph.D. in the field of industrial design [11]. In the intervening years, we have patented the technology [12] and have developed many generations of prototype guitar under the project name Cool Acoustics [13]. We devised this present study to reveal the extent to which guitars with non-wood soundboards can compete tonally with those of spruce or cedar, thus providing opportunity to corroborate or challenge the viewpoint that wood is acoustically superior.

**Human Factors**

At the outset of the development of our guitars, we determined that nobody really knew what a polymer acoustic guitar could, or should, sound like. A sound that does a wood guitar sound like anyway?” and “How can a good- or bad-sounding polymer guitar be defined?” The evaluation and appreciation of musical instrument sound is based on the complex relationship between the subjective aspects of sound as perceived by the ear and measurable acoustic phenomena produced by the instrument [14]. The latter has been deconstructed into vibration, growth/decay, duration, waveform, intensity and frequency, whilst the former has been divided into pitch, loudness and timbre [15]. Each is nominally affected by instrument design, geometry, materials choices and construction. Sound perception is affected by individual peculiarities of the human ear and our cognitive processing. For example, research in the field of auditory neuroscience has established that sound entering the ear is not directly reflected in what people actually hear. Our minds are known to “fill in” missing fundamentals in sound sources, deceiving us into hearing elements of sounds that are not actually present in the audio spectra [16]. Even master luthiers experience difficulties in discerning very subtle changes in tone following structural changes to an instrument [17].

Another factor to consider is that human perception of sound is an experiential phenomenon, related to aural memories and shaped by personal, social and cultural conditioning. Players and makers interpret good tonal quality from a guitar from their own particular perspectives. Furthermore, people tend not to hear sounds uniformly across the
audible spectrum (20–20,000Hz), and the audible spectrum itself shrinks with age. In summary, one person’s sound perception can be quite different from another’s. Who, then, should decide on the qualities of sound that a new instrument should produce? In the 1970s, the Gibson guitar company assembled a team of scientists to develop its Mark Series acoustic guitars, but the approach ended in a high-profile failure:

There is a relatively recent example of a major guitar-maker taking science on board—and failing to capture musicians with the new guitars. In 1977 Gibson launched the Mark Series acoustic guitars. In the promotional literature for the four new models, the 35, 53, 72 and 81, the company explained how, in the past, improvements to instrument design had come about by trial and error, and luck. “That’s why Gibson chose a new method in its search for a better acoustic guitar—the scientific method.” Gibson’s two-year research plan involved three scientists: a professor of acoustical physics, who recorded and analyzed “voice graphs” of popular guitar designs; a chemical physicist (also director of an institute of molecular biophysics) to oversee structural design; and a professor of acoustics who devised new scientific measuring techniques and an environmental test chamber. But despite all this, the guitars did not prove popular and were soon dropped from the Gibson catalogue. The company returned to their old, proven method of trial and error (and luck), and most players would argue that they returned to making good guitars as a result. Gibson’s high-profile failure deterred many makers from the scientific route [18].

As a result, for the development of our guitars, design decisions were made through a process of making and evaluating instruments rather than by scientific method, guided by the practical know-how and experience of three leading U.K. luthiers: Rob Armstrong, Alan Marshall and the late David Hodson.

### Guitar Sound Workshop

We organized a research workshop entitled “Guitars in Context” prior to embarking on instrument design and development, to gather evidence for the range of sounds that might be acceptable from a polymer acoustic guitar and to document the language that people use to describe guitar tonal qualities [19]. Guitar-makers, guitarists and enthusiasts of guitar music gathered in an informal setting where they played, listened to and discussed guitars and relationships between instrument types and sound.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Type</th>
<th>Soundboard</th>
<th>Other Components</th>
<th>Recorded Test?</th>
<th>Live Test?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rob Armstrong No. 673 “30 Year Anniversary”</td>
<td>Wood</td>
<td>Spruce</td>
<td>Fiddleback mahogany (back, sides)</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mahogany (neck)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Rio rosewood (fretboard, bridge)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rob Armstrong No. 691 “RA1”</td>
<td>Polymer</td>
<td>Foamed polycarbonate</td>
<td>Laminated birch plywood (back, sides)</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mahogany (neck)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rosewood (fretboard, bridge)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilgrim Model 1 No. 645</td>
<td>Polymer</td>
<td>Cedar</td>
<td>Glass fiber reinforced plastic (back, sides)</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Laminated mahogany and maple (neck)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rosewood (fretboard, bridge)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rob Armstrong No. 793 “Modified Pilgrim Model 1”</td>
<td>Polymer</td>
<td>Foamed polycarbonate</td>
<td>Glass fiber reinforced plastic (back, sides)</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Laminated mahogany and maple (neck)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Rosewood (fretboard, bridge)</td>
<td></td>
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</tbody>
</table>
The workshop also confirmed that the concept of a “better guitar” has no useful meaning if detached from the context of a specific musical performance. The more rational stance, we find, is to view the use of alternatives to wood as a way of equaling or extending the sonic versatility of wood acoustic guitars while offering differentiation in aesthetics, product semantics, production, assembly and cost.

The workshop revealed that there was no “ideal” guitar sound to aim for but rather a range of sounds that could be interpreted by most people as being guitar-like. More importantly, guitar sounds were revealed as inextricably linked with musical endeavor. Certain tonal qualities were demanded for gypsy jazz (e.g. vigorous plectrum strumming), others for classical pieces (e.g. individual finger strokes), still others for flamenco (e.g. percussive) and so on. No single guitar can excel in multiple musical styles. This partly explains why enthusiast guitarists possess a collection of guitars, each of which has special sonic characteristics suited to a particular musical style or even a particular composition.

The workshop also confirmed that the question whether or not girls could receive the sound from guitars having wood or foamed polycarbonate soundboards was conceived and developed and invited to participate in the sound perception test.

Participants (n = 320) listened to a digital audio file lasting approximately 3 minutes and then answered a questionnaire containing three Likert scale questions (sound quality of recording 1; sound quality of recording 2; closeness of sound of recordings 1 and 2); one identity question (which recording was polymer?); and some demographic information. The digital audio file comprised (a) an instructional introduction, (b) four 30-second musical excerpts played on guitar 1, (c) notification of a change of guitar, (d) the same four excerpts played on guitar 2, and (e) a closing thank you. The two guitars chosen for the test were Rob Armstrong 673 (wood) and 691 (polymer). For the Edinburgh and Worksop tests, guitar 1 was the polymer guitar, while guitar 2 was the wood guitar. The order was reversed for the Croydon and Loughborough tests to see if the playing order had an effect on the results.

The correct identification of a musical source has previously been studied in the context of English cathedral choral music [22]: It was examined whether listeners could correctly discriminate male (usual) from female (unusual) soprano choristers. The study was motivated by the question whether or not girls could accordingly analyzed the field study data to try and establish the existence of such a relationship, using triangulation via the following research questions.

- **RQ1.** Can participants correctly identify a performance made on a polymer acoustic guitar?
- **RQ2.** How close do participants perceive the sound from guitars having wood or foamed polycarbonate soundboards to be?
- **RQ3.** Can participants discern a significant difference in sound quality between acoustic guitars having soundboards made of wood and those with soundboards made of foamed polycarbonate?

### Recorded Test
We administered the recorded test as an interactive exhibit within the “Quick On The Draw” exhibition [21], which toured four locations in the United Kingdom during 2008 and 2009: Edinburgh (City Art Centre), Worksop (Harley Gallery), Croydon (Clocktower Museum) and Loughborough (University). Members of the public visiting the exhibition were exposed to information on how our guitars were conceived and developed and were invited to participate in the sound perception test.

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Participants (n)</th>
<th>Proportion of ALL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>ALL</td>
<td>320</td>
<td>100</td>
</tr>
<tr>
<td>G2</td>
<td>Edinburgh</td>
<td>73</td>
<td>23</td>
</tr>
<tr>
<td>G3</td>
<td>Workshop</td>
<td>98</td>
<td>31</td>
</tr>
<tr>
<td>G4</td>
<td>Croydon</td>
<td>125</td>
<td>39</td>
</tr>
<tr>
<td>G5</td>
<td>Loughborough</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>G6</td>
<td>Guitarists</td>
<td>92</td>
<td>29</td>
</tr>
<tr>
<td>G7</td>
<td>Other musicians</td>
<td>70</td>
<td>22</td>
</tr>
<tr>
<td>G8</td>
<td>Males</td>
<td>121</td>
<td>38</td>
</tr>
<tr>
<td>G9</td>
<td>Females</td>
<td>122</td>
<td>38</td>
</tr>
<tr>
<td>G10</td>
<td>Age 0–5</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>G11</td>
<td>Age 6–10</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>G12</td>
<td>Age 11–18</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>G13</td>
<td>Age 19–21</td>
<td>22</td>
<td>7</td>
</tr>
<tr>
<td>G14</td>
<td>Age 22–25</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>G15</td>
<td>Age 26–35</td>
<td>38</td>
<td>12</td>
</tr>
<tr>
<td>G16</td>
<td>Age 36–45</td>
<td>41</td>
<td>13</td>
</tr>
<tr>
<td>G17</td>
<td>Age 46–55</td>
<td>53</td>
<td>17</td>
</tr>
<tr>
<td>G18</td>
<td>Age 56–65</td>
<td>47</td>
<td>15</td>
</tr>
<tr>
<td>G19</td>
<td>Age 66+</td>
<td>41</td>
<td>13</td>
</tr>
</tbody>
</table>

Unfortunately, this is symptomatic of a lack of understanding of the complex underlying criteria. The more rational stance, we find, is to view the use of alternatives to wood as a way of equaling or extending the sonic versatility of wood acoustic guitars while offering differentiation in aesthetics, product semantics, production, assembly and cost.

### Sound Evaluation Methodology
We arranged a field study to investigate the comparative tonal qualities of wood and polymer acoustic guitars. We conducted two separate blind sound perception tests: test 1 evaluated recorded musical excerpts; test 2 evaluated musical excerpts played live. The guitars selected for the tests, including a fully wood reference guitar, are listed in Table 1 and illustrated in Fig. 1. All of the guitars were handcrafted in the U.K., either by Rob Armstrong or, for the Pilgrim Model 1 series, by a team of skilled craft workers. With only high-quality luthier-built instruments being studied, any differences in tonal qualities would not be attributable to poor construction. An optimistic null hypothesis was set: that there was no relation between guitar soundboard materials and perceived sound quality. We

Table 2. Division of Recorded Test Participants for Data Analysis.
impert an appropriate choral sound. A major factor in participants’ successful identification of gender was the choice of music performed. For this reason, we chose four stylistically different pieces for the tests. These pieces were also free from copyright and royalties, which was a requirement for public performance. Co-author Norman is an experienced ceilidh guitarist who performed the excerpts as consistently as possible. The four excerpts performed for recordings 1 and 2 were (in order of performance):

- **Michael Turner’s Waltz**: An 18th-century waltz from Sussex, U.K., sometimes associated with Mozart because he used the tune.
- **Josh White (Introduction)**: Introduction to a 1930s blues track by Josh White.
- **Tralee Jail**: A traditional Irish Kerry polka.
- **Sheebeg Sheemore**: Reputedly the first tune written by the blind 18th-century Irish harper Turlough O’Carolan.

Table 2 details the 19 non-exclusive groups (G1–G19) that we used as a basis for the data analysis. The age distribution of participants fitted a generally rising trend rather than a normal distribution (mean age = 36–45 years); males and females (not all participants indicated a gender).

The qualitative data from the Likert scale questions were converted to numerical data using the following coding process. For sound quality perception, the coding was: terrible (d = 1), poor (d = 2), good (d = 3), excellent (d = 4); and for similarity judgment, completely different (d = 1), different (d = 2), similar (d = 3), identical (d = 4).

**Recorded Test Technical Set-Up**

The test guitars had been fitted with new strings and were tuned to concert pitch (A = 440Hz). Digital audio recordings (WAV, 44.1kHz, 16bit, monaural) were made using the following equipment and software: Behringer B-1 microphone, 2 x MOTU Pre8 A/D converter Firewire digital audio interfaces, Dell Intel Quad Core Extreme workstation (2.66GHz, 2GB RAM), Sonar Home Studio 6 multi-track audio recording software, Carlsbro Black Box amplifier, and JPW Mini Monitor speakers. We tidied and edited the audio recordings using Steinberg Wavelab 5: removing silence at the start and finish, normalizing the data and splicing together the test instructions with the musical excerpts. We converted the master WAV file to MP3 format and stored it on an SD card for playback at the exhibition through a concealed In-Out PanelPlayer.

To minimize external influences on the quality of the sound recordings, the following factors were considered:

- All recordings were made in the same location: a quiet carpeted office with minimal natural reverberation and background noise.
- The playing style was consistent (e.g. playing with “fleshy fingers” creates a different sound to picked notes; hugging the guitar sound box while playing results in a dampened sound compared to playing a guitar relatively unsupported).
- The microphone was placed directly facing the sound hole at a distance of 30cm.

**Live Test**

The live test was a modest additional study carried out to see if noticeable differences in results would be obtained when guitars were played live to an audience rather than audio recorded. The test asked eight adult participants to listen to and to grade 20-second musical excerpts played on guitars behind a cloth screen; the participants were therefore blind to which guitar was being played when. We carried out the test at the end of a seminar held during the Quick On
The Draw exhibition at Loughborough University, in a carpeted lecture theater with little reverberation. The test was carried out independently of the recorded test at Loughborough. Participants sat approximately 10 meters distant from the cloth screen. All of the guitars had been fitted with new strings and were tuned to concert pitch (A = 440Hz). As with the recorded test, co-author Norman performed the musical excerpts as consistently as possible. The two chosen musical pieces represented contrasting styles. The total duration of the test was approximately 15 minutes.

The test involved 12 paired guitar performances (Table 3), alternating between pairs of guitars from the four instruments shown in Fig. 1. Each guitar was therefore graded on six separate occasions. The test questionnaire contained three Likert scale questions (sound quality of guitar 1; sound quality of guitar 2; closeness of sound from guitar 1 and 2); one identity question (which guitar, if any, was polymer?); and some demographic information. As with the recorded test, the qualitative data from the Likert scale questions were converted to numerical data through a coding process. For sound quality perception, the coding was: terrible (d = 1), poor (d = 2), OK (d = 3), good (d = 4), excellent (d = 5); and for similarity judgment, completely different (d = 1), different (d = 2), similar (d = 3), identical (d = 4).

**RESULTS—RECORDED TEST**

Data from the recorded test were evaluated according to (1) sound quality, (2) similarity of sounds and (3) attempted identification of the polymer guitar.

**Sound Quality**

Individually, participants used the full range of grades in evaluating the sound quality of the guitars, from terrible (d = 1) to excellent (d = 4). This reinforces the point that musical evaluations are a matter of individual interpretation and taste.

Figure 2 visualizes mean sound quality grades divided into different participant groups. The mean ratings for each group were remarkably close, with all data within the descriptive range good (d = 3) to excellent (d = 4). This reinforces the point that musical evaluations are a matter of individual interpretation and taste.

For the “ALL” group, the mean rating was d = 3.32, σ = 0.62 versus d = 3.36, σ = 0.65. The result of a paired t-test for the wood and polymer guitars was p = 0.33 (α = 0.05). Therefore no statistically significant quality gap could be discerned between the wood and polymer guitars. Amongst the location groups, only the Loughborough group revealed a noticeable difference in the gradings: the polymer guitar (d = 3.71, σ = 0.46) was graded higher than the wood guitar (d = 3.17, σ = 0.38). The reason for this discrepancy is unknown.

Those participants with nominally “better trained ears” (i.e. the “guitarists” and “other musicians” groups) also graded the sound quality of both guitars as essentially identical.

It is worth noting that irrespective of location, participants on average graded the sound quality of the first guitar as slightly lesser than the second guitar (d = 3.25, σ = 0.63 versus d = 3.46, σ = 0.64), despite the sound files being purposefully swapped for the locations. This indicates that an order effect might have been present that influenced participants’ evaluations in favor of the second recording that they heard.

**Similarity of Sounds**

Figure 3 visualizes similarity judgments of the sound produced by the wood and polymer guitars divided into different participant groups. Individually, participants again used the full range of possible grades to evaluate similarity, from completely different (d = 1) to identical (d = 4). For the “ALL” group, the mean similarity rating was d = 2.66 (σ = 0.69),
which qualitatively corresponded to midway between different (d = 2) and similar (d = 3). This shows that there was no consensus on the guitars being either obviously similar or obviously different. This rather inconclusive finding was repeated across all participant groups, including among guitarists and other musicians. It was therefore necessary to determine, from the overall data set, which grade was used most by participants. The result was 85 participants grading as different (d = 2) and 195 participants grading as similar (d = 3). On this basis, the collected data shows that over twice the number of participants regarded the sound of the guitars to be similar than those who regarded the sound to be different.

**Attempted Identification of the Polymer Guitar**

Figure 4 visualizes the proportion of participants within different groups who correctly identified the polymer guitar from amongst the two recordings. From the “ALL” group, 51% correctly identified the polymer guitar; 51% cannot be considered better than a two-way guess as to which was the polymer guitar. Similarly, guitarists and other musicians had a success rate of 50% and 54% respectively in correctly identifying the polymer guitars. However, greater variation in success was noticed amongst participants divided by location. The correct identification steadily declined as the location changed (Edinburgh 65%, Worksop 58%, Croydon 42%, Loughborough 33%). The serially falling success rate might have arisen because the participant profile tended to be younger, and perhaps less acoustically trained, in each respective location (the proportion of participants younger than 36 years were: Edinburgh 41%, Worksop 23%, Croydon 49%, Loughborough 79%). However, no causal relationship can be conclusively demonstrated. A re-analysis has therefore been performed in the attempt to find a better possible explanation for the serially decreasing success rate, based on age distribution.

**RESULTS—LIVE TEST**

Data from the live test were subjected to the same three evaluations as the recorded test. The results of the sound quality rating of guitars are shown in Fig. 5. It can be seen that grading of the guitars for each test pair ranged from d = 2.88 (poor-to-OK) to d = 4.25 (good-to-excellent). The grading range for the Rob Armstrong No. 673 wood guitar was noticeably narrow compared with the others, which can be interpreted to show a consensus among participants on the sound quality of that particular guitar. The mean results of perceived sound quality, from highest to lowest score, calculated for all 12 test pairs, were: Rob Armstrong No. 691 polymer guitar (d = 3.75, σ = 0.45), Rob Armstrong No. 793 polymer guitar (d = 3.56, σ = 0.46), Rob Armstrong No. 673 wood guitar (d = 3.52, σ = 0.12) and Pilgrim Model 1 No. 645 polymer guitar (d = 3.40, σ = 0.41). All of these mean values are sufficiently close (i.e. all “OK-to-good”) to support the conclusion that differences in sound quality between the guitars were not really discernible to the participants.

The average grade for the similarity of the guitar sounds, calculated for all 12 test pairs, was d = 2.48 (σ = 0.18), corresponding to a qualitative grading midway between different (d = 2) and similar (d = 3). This repeats the finding of the similarity question from the recorded test. In an attempt to determine a more firm result, a count was again made of the number of occasions in which participants graded as different (d = 2) or similar (d = 3), from a total of 96 possible occasions (8 participants, 12 tests). The result was also inconclusive: different (2) given on 49% of occasions and similar (3) given on 42% of occasions. On this basis, the live listening test failed to show a consensus among participants that the guitar sounds were either generally similar or generally different. They were mixed.

Figure 6 shows the proportion of participants for each test pair who either incorrectly identified, correctly identified or did not know which of the guitars played, if any, was polymer. On average, across all test pairs, only on 15% of occasions did the participants correctly identify the polymer guitar. Furthermore, on 43% of occasions, participants indicated that they either did not know which guitar(s) were polymer or they made an incorrect identification. It was clearly very difficult for the participants to discern whether a polymer or wood guitar was being played during the live performance.

**CONCLUSIONS**

The research presented in this paper has provided an initial comparison of the public’s perception of sound originating from acoustic guitars made from traditional materials (wood) and non-traditional materials (thermoplastics and other synthetic polymers). One of the major motivations has been to gather
different from those of the full sample of musicians, possessing a more “well-touched” character, and so a great challenge for polymer instrument development is to engender a wider desirability of plastics, capable of overturning people’s prejudices or shifting existing tastes.

Furthermore, the success of an innovative instrument or use of a new material really can be judged only when composers and musicians have had time to creatively explore an instrument’s possibilities. This has been the case for English guitarist Gordon Giltrap, who has shown his enthusiasm by recording a recent studio album entirely on a polymer instrument [23].

References

Glossary
archetypal product—A product for which the function and form have reached a developmental plateau resulting in little or no substantial variation. Contrast this with “evolutionary” and “historicist” products.
likert scale—a linear grading system typically used to capture people’s evaluations or opinions of something, for example to grade it as “very good,” “good,” “neither good nor bad,” “bad” or “very bad.”
σ—Lowercase sigma used to indicate standard deviation.

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Owain Pedgley undertakes research in materials and manufacturing for industrial design and user-product experiences, with a special emphasis on musician-instrument interaction. Pedgley is a partner in the musical instrument innovation project Cool Acoustics. He contributes to design education at bachelor, master and doctoral levels and is experienced in establishing and managing collaborative industrial projects with firms including Nokia, Bosch-Siemens and Vestel. He previously served 3 years as a product designer in the sports equipment sector.

Eddie Norman’s research concerns the relationship of technologies and designing in relation to general and higher education and associated pedagogical issues. Norman is a partner in the musical instrument innovation project Cool Acoustics. He is leader of the Design Education Research Group, has contributed to teaching on undergraduate and masters programs, and is Editor of Design and Technology Education: An International Journal. Norman has previous careers both in secondary education and as a professional engineer.