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# STEM@1000mph: Developing Open Educational Resources in a Live Engineering Project

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**Abstract:** Higher education institutions are recognising the clear benefits of open educational resources, and academics are engaging with the development of these resources. This paper presents a case study of OERs being developed using the live, current BloodhoundSSC world land speed record project as a basis. The paper outlines the rationale for the BloodhoundSSC project and its focus on educational engagement across the age spectrum. The work undertaken to develop a web-based repository along with activities to stimulate academic and student engagement are described. The paper explores how academics have engaged with developing OERs based on this openly available content, the issues encountered and ways in which these issues can be mitigated.

**Keywords:** OER, BloodhoundSSC, Live Engineering Project, STEM

## Introduction

The Bloodhound Supersonic Car (BloodhoundSSC) project (http://www.bloodhoundssc.com/) arose through recognition that key UK industrial and government employers were struggling to recruit sufficient skilled engineers and scientists at all levels. The BloodhoundSSC project was conceived with the aim of encouraging more young people into Science, Technology, Engineering and Mathematics (STEM) by taking an open access approach to the challenge of designing, building and running a car capable of raising the world land speed record (WLSR) to 1000 mph. Unlike other sectors of high technical innovation, such as Formula 1, the unique and varied nature of WLSR cars, and the fact that teams building WLSR cars are competing with nature and not each other means that the project can be open about the challenges involved and the solutions adopted, without fear that another team may copy the design.

To address this aspiration to inspire a future generation of scientists and engineers, the BloodhoundSSC project is structured into two threads: the engineering team, responsible for the design, development and testing of the land speed record car; and the education team, responsible for the education engagement activities. The focus of the educational activities would be to interface and integrate BloodhoundSSC-based information within existing STEM enrichment activities in primary and secondary schools.

It was recognised that these educational activities could also benefit STEM teaching and learning in Higher Education (HE), and this resulted in the formation of Bloodhound@University. The aim of this initiative was aligned to the wider educational activities but focused on exploring how a live, highly challenging engineering project could be used to engage, enhance and enrich STEM based teaching and learning at the university level. This would be achieved through the development of a repository of teaching and learning Open Educational Resources (OER) based upon the current and live outcomes of the BloodhoundSSC project.

There are clear benefits of producing OER and there are many studies supporting this, for example Johnstone (2005) and Caswell et al (2008). For higher education institutions, these benefits include economies of scale, marketing and community building (JISC 2012). Indeed, Hylén (2006) argues that positive effects include broader and faster dissemination leading to rapid quality improvement and faster technical development, which is exactly what the educational aspect of the BloodhoundSSC project is trying to achieve.

This paper reports on the experience of producing OER based on a live, current project, discussing its implementation, giving an overview of the content being created, and identifying issues that have arisen and strategies to mitigate these issues. While the engagement of universities with the development of open educational resources is not new, using a live, current and developing project as a basis for these resources is novel and worthy of exploration.

## The Vision

Bloodhound@University was conceived as a consequence of the University of the West of England's sponsorship of the BloodhoundSSC project. Although the main focus of the educational activities of BloodhoundSSC is on primary and secondary education, it was recognised that the HE community could also benefit from the open aspect of this live engineering project. At the earlier educational levels, there is a lighter demand for highly detailed information on the car and the project and, whilst the engineering team make information available, the school level activities (Balloon Cars, Bloodhound F1 in Schools) do not require any substantive or detailed information of the car or its systems. At the HE level, the access that BloodhoundSSC provides to design information, system details and test run data is unlike that which is possible from the majority of engineering projects in the commercial and government arena. Normal competitive, commercial and government security constraints mean that the majority of the details or projects are not shared, and that the information that is available to education is largely superficial. The limitations and weaknesses of the details, challenges and adopted solutions are often hidden. The open access nature of the BloodhoundSSC project gives a rare and unrivalled opportunity to provide students with a richness of detail rarely found in data on industrial projects along with access to information on the ideas that worked, the ones that did not and the lessons learnt from those failures.

The key objective of Bloodhound@University is to provide access for academics and students to live project-level information including the research, design, testing and running data as the project progresses. Whilst access to this information can provide interesting technical content for academics and students, it was recognised in the early phase of the project that it would be more beneficial if the 'raw' project information could be developed into OER to facilitate wider adoption, usage and engagement with the data from the project. The attraction for academics would be a leveraging of their effort: in return for producing one set of OER, access would be granted to a library of OER produced by colleagues in the community. In addition, the open nature of the project would also provide ideas and competitions for students linked to the activities. For many studying STEM subjects, getting involved in a ground-breaking challenge such as this is very attractive and stimulating. Lastly, Bloodhound@University facilitates the exploration of how the open intellectual property (IP) and patent-free policies of the BloodhoundSSC project could transfer to sectors where IP protection is seen as precluding, limiting or inhibiting collaboration.

## The Repository

A Special Interest Group (SIG) was established as part of Bloodhound@University, comprising academics from higher education institutions interested in building a community to deliver the objectives.

The first activity for this SIG was to identify an IT platform to host and support the activities. Transferring project information request and out-feeds through an informal channel (such as through a contact on the engineering team) was impractical and a collaborative web-based platform was required. A repository similar to HumBox, developed by the University of Southampton for the widely distributed Humanities education community, was deemed a suitable solution that could support a community of HE academics in developing and sharing resources. This has been shown to lead to innovations in practice, fostering the integration of open practice with day-to-day academic life (Millard et al 2009a; Millard et al 2009b). HumBox provided an exemplar of how a user friendly system supports on-going engagement with a community, and works towards changing users' attitudes and behaviour regarding OER and sharing of teaching materials (McSweeney et al 2011). Key advantages of this system are: its collaborative capabilities allowing dynamic co-creating of content by users; its ease of use in supporting multimedia content; its ability to index using metadata; and its ability to facilitate re-purposing and addition of materials to create new content. Furthermore, the platform enables content evolution to be backtracked providing access to both current generation and antecedent documents and material.

The repository for Bloodhound@University was given a working title 'K-Box' (Knowledge Box) and once implemented, is used to host Bloodhound@University generated content. In addition to hosting teaching materials, the K-Box is also being used to host the 'raw' BloodhoundSSC project data that is being archived by the engineering team to establish a legacy repository that will be accessible after the BloodhoundSSC project completes. The service manages the release of the engineering resources to the HE community where it will be used as a primary source to create new and remixed OERs. All content in the K-Box is licenced as accessible for use and reuse under a Creative Commons license as the default position. Items in the repository vary from reports, presentation slides, data files, mathematical models, computer aided design (CAD) and computational fluid dynamics (CFD) data.

## The Content

Bloodhound@University secured funding from the Engineering and Physical Sciences Research Council to provide small grants to academics and others willing to produce OERs to be shared through the K-Box with other academics and teachers. This approach was used to effectively 'seed' the repository and provide a series of starting points from which others would then develop and adapt material.

A variety of activities were undertaken, a list of which is supplied in the appendix. Many of the activities took information from the publicly available vehicle technical specifications, CAD data and development data to produce case study reports, presentations, assignments and Bloodhound-specific software tools to support teaching and learning not only in HE environments, but also adaptable for lower level education. How effective the outcomes of these activities prove to be in stimulating engagement and use by academics and students is yet to be determined, and will form a component of future work.

Unlike other engineering projects in which educational materials have been produced post-project, with BloodhoundSSC the development of OERs is proceeding in tandem with the development of the engineering aspects of the car-building project. Whilst this can cause complexity, for example when information and specific details required by academics are unavailable, it does allow a novel form of interaction in which the educational community is also able to contribute to the project development in a mutually beneficial manner. One of the early student assignments on K-Box was based on the development of the driver's steering wheel. Unlike the steering wheel used in ThrustSSC (the previous WLSR car), as shown in Figure 1, the BloodhoundSSC steering wheel has to have a degree of fit, functionality and form closer to that of a Formula 1 steering wheel with both driver controls and feedback information.

Figure 1: Steering wheel for ThrustSSC (Source: BloodhoundSSC)

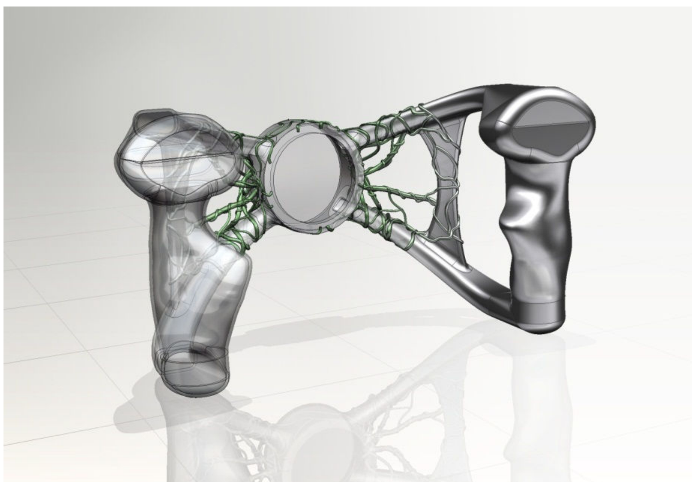

An initial ergonomic study was undertaken with a group of product design students (based at the University of the West of England) who worked with the driver of BloodhoundSSC on the shape of the steering wheel and the cockpit. Using the results of this study, some proposed solutions were progressed to form a more detailed functional prototype through a student placement with the engineering team. When the engineering team needed some further user and performance requirements factored into the steering wheel design the problem was formed into a project brief centred on ensuring the steering wheel would be stiff enough to meet the loads imposed by the driver and the car, whilst reducing weight - a classic design optimisation problem.

This brief was then set as an assignment to a group of final year engineering students whose programme of study included a two-week intensive design case study activity. The output from the brief given to the students was a set of some 25 different topological solutions (some shown in Figure 2) that had been designed and modelled in CAD and analysed using finite element analysis methods.

Figure 2: Sixteen examples of 'crowd sourced' steering wheels, with top ranked selections shown on right. (Source: Bloodhound@University K-Box)

Subsequent to this assignment, the engineering team and driver selected elements of the students' proposals and made a step change in the design and structure of the steering wheel. Prior to the student involvement the engineering team were achieving one design iteration per month by the engineer tasked with this aspect of the work. Harnessing the 'crowd-source' effect of the student groups delivered, in two weeks, a group of solutions equivalent to approximately two years of engineering work complete with finely detailed CAD and load models that could be fed into the engineering team's thinking and work. A finalised prototype design of the steering wheel is shown in figure 3.

Figure 3: Finalised prototype steering wheel design. (Source: Bloodhound@University K-Box)



Interactions have not been limited to explicit STEM subjects. An activity was run with the support of the Meteorological Office to install a weather station on Hakskeen Pan, the run site in South Africa, to collect environmental data. This data are primarily used by the team to assess the duration of the suitable weather window prior to travelling and operating on the site. A student activity at a further education college was run to set-up, configure and then access the data streams from the run site. This data, whilst primarily intended for team use, have also been made available to wider audiences to support geography and related environmental subjects.

## Issues

The novel concept of developing open access teaching content alongside a live and challenging engineering project offers great potential to provide a rich source of teaching material across the university curriculum. When attempting to integrate education this closely into the design and development of a car as technically challenging and complex as BloodhoundSSC, various issues have arisen. Principally issues have related to the transfer of information and data between the engineering team and the academics working on developing OER based on this data.

1. **Engineering team members allowing work to be shared:** this issue was not originally foreseen, but some engineers were concerned that others could assess his or her competency from the detail of the design and identify errors and omissions. Open peer review might be more widespread amongst academics, but it is less common in industry and exposing an individual's technical work to a wider public audience has been a challenge for some of the members of the engineering team.
2. **Obtaining clarity in terms of details on the car design:** Depending on the request from academics, some clarification was required from the engineering team, and in certain cases, the engineering team were unable or unwilling to release data due to impending design reviews or decisions that could result in major changes in the design. Such requests included material choice for wheels, aerodynamic loading data or suspension design details. Invariably, clarification questions from the academic community arose from the specific technical interest of the academic, and these were not always aligned with the engineering team's priorities.
3. **Component and file naming conventions and file structures:** the relatively flat team structure of the BloodhoundSSC engineering team allowed individual engineers to adopt different methods for storing and categorising information and data, and resulted in inconsistency in the terminology used for components and vehicle subsystems. Collating data about a specific aspect of the car was therefore problematic, as the component names and file storage structures were sometimes inconsistent.
4. **File formats:** Ensuring that the file formats are compatible with the systems used by academics has proved problematic. For example, with CAD files, some formats are proprietary to the software package, while others are useable across several platforms.
5. **Capturing rationale for design decisions:** Whilst it is relatively easy to make design and development data open for adaptation, it has been in some instances difficult to ascertain how and why specific design choices were made. It is clear that direct access to the engineering team is impractical and unsustainable due to pressures to deliver the car. Accurately capturing the design rationale and narrative of the evolution of the car has proven to be a key challenge, despite forming an integral part of the engineering process and hence a key aspect of engineering education that academics may wish to exploit in their teaching.

In addition to the above, there have been issues relating to intellectual property

(IP). Whilst the BloodhoundSSC project as a whole is committed to open access and not pursuing any patents, a number of sponsor companies who have contributed protected IP to the project require that detailed engineering information about their systems is not made public. An example is information about the Formula 1 engine supplied by Cosworth, which is used to drive the rocket fuel pump. In addition, IP issues have also arisen in relation to analyses of test data that could potentially be used to reverse engineer parameters of IP protected subsystems. It is unlikely that this issue can be mitigated due to the commercial partners involved being unwilling to lift their restrictions on data release.

## Strategies to mitigate issues

Whilst the BloodhoundSSC project is committed to education, the engineering team has the imperative to design, test and run the car, and the relationship between the two facets of the project needs careful management. Through close liaison with the engineering team, the educational team has worked to reach mutually agreeable compromises and strategies that enable both to achieve their respective objectives, and the implementation of these strategies has helped mitigate issue 1 (engineers' reluctance to release information).

As the project entered the build phase, issues 2, 3 and 4 listed previously (clarity of details, terminology and file structures and formats) have been addressed as the team itself has by necessity imposed control and clarification of design details. If a part is ready to be manufactured, the information required, such as cross checking of details or supplementary information required by the manufacturer, can be provided as a coherent package for educational use. If the development work on a component or subsystem has been completed, there is no reason why the associated details cannot be released for academic use.

A phased and managed release strategy has been adopted that aligns to major project milestones and this has also helped mitigate issue 2 surrounding clarity of information. This harnesses the vehicle based critical path effort of the design team and reduces the requests for information that are peripheral to the design team's focus. Academics do not necessarily require the most up-to-date version of the design details, and adequate detail based on a release that may be four weeks behind the current definitive state of the project can still offer interesting and relatively timely information on the project.

Systemising of the meta-tagging and uploading of this data to the K-Box within the engineering team has helped mitigate issues 3 and 4, which are concerned with terminology and file structures and formats. This also aligns with quality assurance based requirements in the process as they enter the manufacturing phase and is a further example of marrying the requirements of both engineering and education to deliver useful outcomes for both facets of the project.

The link with universities has resulted in mutually beneficial activities. Academics have gained interesting teaching materials and the engineering project has gained from academic and student input. In addition to the steering wheel example another student design exercise produced spreadsheet based simulations of the airbrake system that was subsequently used by the engineering team to validate proposed solutions.

Experience through managing and running the SIG suggests that whilst many academics are fully supportive of the principles and idea of using information about the car, its design, testing and running to produce teaching materials, the pragmatic reality of the pressures on academic staff is such that there is a need to provide some initial development funding that will hopefully trigger further engagement and content development. This is a paradoxical situation of having to fund 'openness', which is not uncommon in OER projects.

Strategies to mitigate issue 5 (capturing design rationale) are ongoing, and one of the funded projects (Case study of the development and design of the rocket propellant pump power source and gearbox) is an investigation into the design process of a subsystem based on videoed interviews with the design engineer. The process of producing this OER will inform strategies on how best to capture design decisions.

## Conclusion

It is clear that projects such as BloodhoundSSC offer a number of opportunities to feed exciting, challenging and developing real-world, live projects into education via the development of OERs. Bloodhound@University was set up to stimulate engagement from the academic community to create, share and reuse teaching materials derived from raw project data. Despite the benefits that developing OERs bring to modern higher education, it is also clear from the experiences that developing OERs based on a live project is not always as straightforward and easy as might be expected from an open access and patent free project. A number of specific issues were highlighted in the study, and strategies to mitigate them were also presented. Establishing a community of users and enthusiasts is a key issue, and is a focus now that a number of the infrastructure and IT process issues have been resolved.

The authors acknowledge that this case study is limited by a lack of evaluation of impact, and as such, this is a key thread of future work. How much of a difference with STEM engagement, retention and performance in HE has this made? This is a complex and difficult to quantify area and there are many factors that can influence, positively or negatively, students' (and academics') engagement with STEM. For example Ryan and Davies (2013) showed the overriding impact that parental attitudes had despite exposure of students to a range of enrichment activities and projects.

Another key focus for future work surrounds the sustainability of the system put in place - not to be confused with the sustainability of open educational resources themselves, which is a different topic, covered extensively in the literature, e.g. Wiley (2006). The issue here is how to sustain the investment made in the process established as part of the Bloodhound@University initiative once the BloodhoundSSC project completes. Another live project needs to be identified and engaged with that can continue to feed the repository with HE-developed OERs. The 2012 London Olympics have passed but infrastructure projects could provide interesting and stimulating platforms for OER based teaching material across the educational spectrum. Additionally projects such as these encompass a wider range of subject areas covering technology, environmental, social and economic aspects and so provide powerful learning opportunities that expose learners to the complexities, interdependencies and conflicts that are commonplace in live projects.

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# Appendix

| Project | Description |
|---|---|
| Application of ALM to Bloodhound | Additive Layer Manufacturing (ALM) case study, detailing process of specification to concept design. Creation of a number of specifications that could be used for student projects. ALM glider competition |
| CFD of Bloodhound Design | Convert 2D FLITE to user-friendly web-based application. Input parameters and return flow patterns. $C_D$ and $C_L$ coefficients. |
| Numerical Modelling in MATLAB | Performance predictions based on MATLAB toolbox development, with three separate teaching resources for programming, numerical methods and optimisation. |
| Front Suspension Upright Design Optimisation | Create feasible minimum weight design. Feeds in to rapid prototyping, experimental mechanics, design validation and life cycle assessment teaching. |
| Environmental Credentios in a Minimum Weight Design Concept | Design for sustainability to eliminate environmental impact of component development and reduce product carbon footprint. Case study using front suspension upright as focus to develop scenarios and teaching material based on life cycle analysis. |
| Novel Design Substantiation and Proof of Concept | Applicable to topology optimised design to mitigate risks and improve design (virtual testing, rapid prototyping, additive manufacturing) from design validation to proof of concept. |
| Real-time Multibody Dynamics model and environment | Non-linear real-time simulation model of BloodhoundSSC to illustrate modelling and simulation practice. Ability to predict vehicle performance, assess design changes and provide demonstrations. |
| Developing awareness of and engagement with BH Education Website | Document most interesting management stories. Highligh how project can maximise engagement value of stories through social media. |
| Science Made Simple | School's workshop based on Bloodhound engineering for HE Widening Participation programmes. Provides presentation slides, equipment list and video. |
| Infohound | Development of a discovery meta-resource for learners, tutors and general public. Artificial Intelligence agent capable of answering BH related questions that will provide a guide to on how to access and use the open access AI interface and how to embed within education activities. |
| Sensor and Interface Technology | Teaching and learning resource (undergraduate resources and outreach) to introduce concept of using sensor tech to collect real-time data. Introduce students to concept behind sensors and familiarise them with electronics and programming tools. |

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| Design Optimisation of air brake bracket | Optimise air brake brackets for weight and performance using ALM. Delivers case study of novel design optimisation techniques including solid models and background about ALM. |
| Development and Design of the Rocket Propellant Pump subsystem | Case study following the design process of subsystem(s). Interview with design engineer to be edited to enhance impact and communication with undergraduate viewers. |