Manufacturing Engineering Tripos - Part II

Report No: 40/13/26
Date: 8/06/04

UNIVERSITY OF CAMBRIDGE

Department of Engineering
Manufacturing and
Management Division

Kinkajou Volume Manufacture

Name: Gareth Sumner

EXECUTIVE SUMMARY

This report examines the future of the Kinkajou Microfilm Projector as preparation for the first large scale test begins. The market potential, volume manufacturing options and project development are all investigated.

The market within adult literacy is assessed beyond that defined by *World Education* in Mali. An estimate of the market size, discussion of the key market and customer characteristics and an investigation into alternative uses are all offered.

A Volume Manufactured Concept is presented and used to illustrate that Kinkajou can be produced at volume with costs well below the target price of $50.

Further improvements are suggested to bring Kinkajou to the next level of development and increase its market appeal and functionality.

Finally the evolution of Kinkajou from a student project to a real world project is discussed.

The report is split into two parts, Part I examines Kinkajou and its future as a product. Part II examines Kinkajou as a project.

CONTENTS

INTRODUCTION

The development of the Kinkajou Microfilm Projector offers a challenging new dimension to *Design that Matters*. For the first time, the organisation is developing a student project into a real world product that will help many thousands of people in the developing world. This will involve a steep learning curve and consideration of a very different and more intense set of issues. In particular the change from a project intended to inspire US students to use their skills to help the developing world, to a project directly helping the developing world, this is a challenging process.

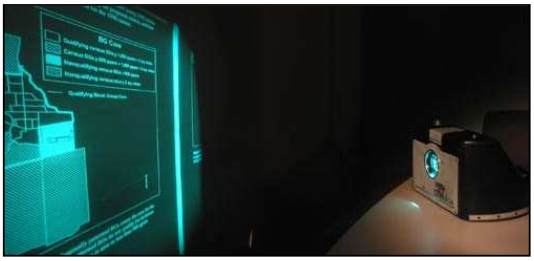
This project analyses Kinkajou and *Design that Matters* at a critical point in their evolution. Kinkajou has been developed for two years and with the backing of *World Education* and USAID has a potential market of nearly 2,000 in Mali alone. The future of *Design that Matters* and Kinkajou depend on the capture of this market and with it, the confirmation that this product can change peoples' lives.

PART I

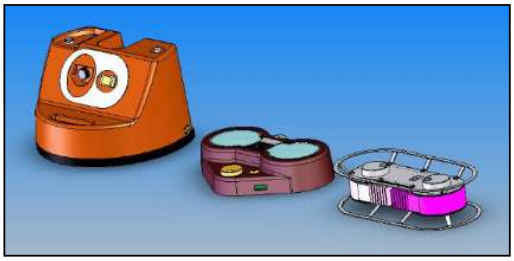
1. THE PRODUCT

1.1 Kinkajou Microfilm Projector

The Kinkajou Microfilm Projector is a product developed and built with the collective effort of over 100 students studying in the Boston, Massachusetts area. A simple-to-use teaching aid for the developing world, the product projects an image onto any flat surface from an internal microfilm library of up to 10,000 pages, the content of which is set during manufacture. Intended for the harshest environments and roughest treatment, the projector is built to be robust and reliable and runs off renewable sources of power.



The Alpha prototype working



From left to right the Alpha, Beta and Gamma Prototypes

1.2 Project Evolution and Status

Since 2001, four design iterations have been developed: Proof of Concept, Alpha, Beta and Gamma Prototypes. The Beta Prototype, during an MIT[1] West African field study in summer 2003, underwent short term testing in rural areas of Mali and Benin.

Beginning in September 2004, *World Education* has arranged a, 6 month test of 75 units. To prepare for this, Design Engineer Allen Armstrong, and Project Engineer Peter Fichtor, have developed the Gamma prototype.

In spring 2005 the Gamma will return from Mali with information on the pedagogical performance and robustness of the product. From here, the aim is to develop a fifth design iteration.

[1] Massachusetts Institute for Technology

1.3 Volume Manufacture and the Future of Kinkajou

The next two chapters of this document and the project it has succeeded look at the position of Kinkajou in spring 2005, examining how to take the project forward to a volume produced, sustainable solution.

2. THE MARKET

Kinkajou has been developed to solve issues presented to *Design that Matters* by *World Education*. *World Education* have remained firm advocates of the project throughout and have confidence that the microfilm projector concept will soon help thousands of people learn to read and write. *World Education* has confirmed that once the product has been proven, they will have a market for 1,700 units in Mali alone. This initial market provides a platform for Kinkajou to establish a firm foot hold in adult literacy, from which it can evolve and develop into other, larger markets.

2.1 Adult Literacy

2.1.1 Target Market

When the product was first conceived, students looked to solve two problems highlighted by *World Education* in their night time literacy classes:

- Inadequate lighting
- Limited access to educational primers

A solution to these two issues was developed, eventually taking the form of the Kinkajou Microfilm Projector.

2.1.2 Confirmation of Need

Research has been carried out with a range of organisations to confirm these issues remain outside of *World Education*. This research has however, shown that adult literacy schemes suffer from a varying spectrum of issues not just confined to those Kinkajou solves. It has also been noted that some policies would actively discourage a solution such as Kinkajou.

The following quote from Digby Swift, DFID[2] Senior Education Advisor for North and West Africa, illustrates this:

[2] (UK) Department for International Development

"The preferred approach for this (adult literacy) is to encourage teachers to develop their own materials and to read locally available and relevant printed material. Even if there is sufficient money to afford background readers then these will be for individuals not for the class."[3]

This view is backed up by other sources, for example, the scheme REFLECT, championed by Action Aid. REFLECT approaches literacy projects by focusing on locally designed and manufactured content and teaching aids.

* * *

There are two main issues which Kinkajou must adapt to:

i. The current belief that any solution must be designed, developed or manufactured locally
ii. The informal settings now commonly used and preferred to schools, for literacy classes, and championed due to historical difficulties with classroom based literacy projects. Classes held outdoors are particularly popular.

Problems of power and insufficient or inappropriate[4] primers (where a primer is used) are still prevalent. The problem is that they are perhaps not considered to be the most pressing issues.

2.1.3 The Role of Kinkajou

If, in adult literacy, Kinkajou solves mainly niche issues, then the more common issues must be investigated. Defining the issues common in adult literacy across the developing world, the following issues are the most important:

- **Access** to literacy schemes
- **Maintaining interest** and levels of literacy
- **Quality of teaching**
- **Context** and quality of curriculum and primers for adults

[3] Digby Swift, DFID: email dated 4.6.2004
[4] A particular issue is that primers specifically designed for adults are very rare.

Given that Kinkajou is not directly aimed at all these issues, to be successful it must:

- Attempt to complement efforts to solve as many of the above as possible
- Not hinder efforts to solve any of these problems

For example if Kinkajou was so difficult to use that good teachers were put off, then it would be a hindrance.

Therefore, the pedagogical advantages must continue to be real, clear and appropriate while at the same time, the disadvantages must also be thoroughly investigated and minimised.

2.1.4 Market Size

With consideration of the above issues the potential market for Kinkajou has been calculated. The details of this can be found in Appendix B, however the results are offered here.

Assuming the issues defined by *World Education*, for which Kinkajou was designed to solve are universal, the market can be estimated as follows:

The **illiterate working adult** population in **rural areas** of **low income countries**[5] where the **illiteracy rate is below 20%.**

A reachable proportion of this has then been taken relative to how many *World Education* believe they could distribute in Mali. This gives the value **111,000.**

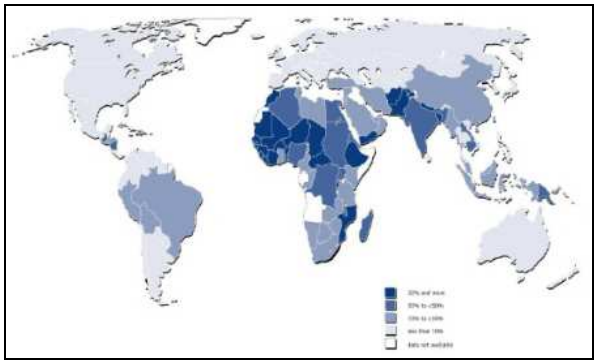
Taking the *World Education* figure and then estimating that 10% of organisations would look to tackle the same two basic issues and also see Kinkajou as appropriate then we have a **market in adult literacy for 11,000 units.**

[5] Based on the World Bank's definition

2.1.5 Target Location

Based on the criterion outlined above, the target market location is centred on the following areas[6]:

- West, North and Central Africa
- The Middle East and South Asia
- Central America



The main market locations for Kinkajou

All these locations vary greatly in needs, climate and infrastructure, leading to the problem that a one-size-fits-all product and service will not be appropriate for all locations. This is further discussed in Section 2.5.

2.2 Other Applications

In order to expand it's market, Kinkajou should look beyond night time adult literacy classes and utilise the product's versatility as far as possible. In order to identify this wider market we must look at what Kinkajou does:

Kinkajou projects pre-recorded images and text onto a flat surface for up to 25 people to view at once. It is portable, robust and rechargeable in remote locations.

[6] A country by country break down is available in Appendix B

2.2.1 Adult Vocational Training

With the above definition in mind, an appropriate use may be that of general adult training. Topics such as health awareness including AIDS, vocational on-the-job training and community projects such as how to build a well may all be appropriate.

2.2.2 Private Schools

In private schools money would be available if Kinkajou was proved to be highly advantageous to the school. If the ownership of a Kinkajou by a school was seen as a status symbol, then it may be particularly attractive.

2.2.3 A Complementary Device

Although the projector is designed for areas with no power or books, there may be a market in better equipped classrooms as a complementary device. Battery power may be more reliable than mains supply and the ability to display pre-recorded data to the whole class at once may be more beneficial than just using textbooks. This route has not been investigated, but it is recommended for further consideration.

2.2.4 Daytime use

The main hurdle to using Kinkajou for these applications is a lack of image contrast, rendering it difficult to view the image during daylight. If this issue could be solved, then the market for the above applications could potentially be many times larger than the market in adult literacy.

2.3 The Customer

The users and main beneficiaries of the product are described above; however the customer and distributor will, in most cases, be a third party.

Organisations working in developing world educational projects can be spilt into three categories; these are described in Appendix C. The most appropriate of these, as a Kinkajou customer, is Non-Government Organisations (NGOs).

Differing opinion and policy between organisations within the NGO sector is common and often developed into rigid policy, particularly in larger NGOs. This policy will dictate whether Kinkajou would be appropriate.

It is therefore recommended that small NGOs be the first target customer for the introduction of Kinkajou.

2.4 Cost

Cost is a basic threshold characteristic; a product will only be purchased if:

i. The money is available

-AND-

ii. If the benefits greatly outweigh the cost

The level of the threshold is difficult to quantify and varies greatly between countries and organisations. It can only be said that it must universally be the lowest possible price.

2.5 Product Variation

There are a number of areas where the market variability directly affects Kinkajou as a product and the way *Design that Matters* distribute it:

2.5.1 Function and physical design of product

Not all locations face the same issues in adult literacy as those described above, therefore subtley different designs may be necessary. For example the following may change: Power requirements (including availability and levels of UV for solar charging), physical robustness, colour and aesthetics and their political or religious implications.

2.5.2 Microfilm content

The content has to be carefully contextualised and well designed for the people who are using the material; this is likely to be to at a country level.

2.5.3 Distribution and types of customer

The structure of the selling and distribution process will vary greatly particularly as new applications are created, both due to physical and geographical issues as well as political considerations.

2.6 Market Conclusions

The market for a teaching aid which solves the same problems as Kinkajou, is potentially **11,000** in adult literacy. This market is characterised by **variability and uncertainty** and is spread over a wide **variety of locations and organisations** with **differing needs**.

With the market in Mali under *World Education* being estimated at 1,700, Kinkajou has a perfect opportunity to reach a state of confidence by which the extended adult literacy market can be captured and even expanded upon.

There is also great potential for Kinkajou's use to diversify into other applications, particularly if the image contrast can be improved for daylight use. This could increase the size of the market many times over.

With the above considerations it is recommended that:

- Individual batches of **5,000 units** are planned for
- Each project would require around **1,000-2,000 units**

3. VOLUME MANUFACTURE

Market research has recommended that 5,000 units should be planned per batch. This chapter looks at the manufacturing options available at these numbers as well as, for completeness, volumes of 1,000, 25,000 and 50,000.

3.1 A Starting Point

The most recent design iteration is the Gamma Prototype to be tested in Mali. It is characterised as follows:

- Single manufacturing batch of 75
- Minimum 6 month lifetime
- Must generate feedback on pedagogical and reliability issues

With these issues considered, it is not appropriate to assume a simple evolution into a volume manufactured product. Instead a concept is developed with reference to lessons learnt and ideas from all prototypes and other similar products.

A design is offered to illustrate the issues involved in designing the product for volume manufacture and what can be achieved using the manufacturing process. The design also incorporates new design features added for functionality

Due to time constraints certain concepts have been carried forward directly from the Gamma. This is detailed in Appendix D.4

To enable lessons to be learnt from the Gamma, an analysis of the prototype is offered in Appendix D.

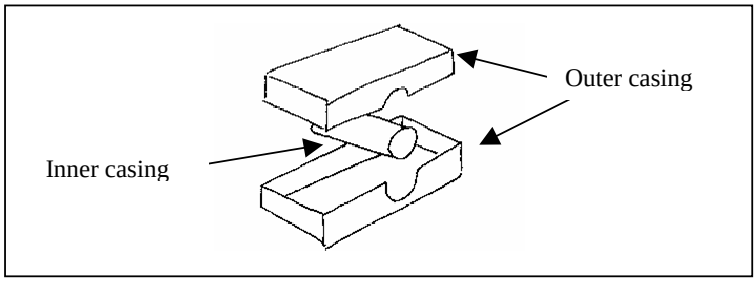
3.2 Component Grouping

Evaluating the major functional components of Kinkajou, they can be split into two groups:

Tolerance Critical Components: Components whose functionality is dependent on their accurate relative alignment
These are: ***condenser lenses***, ***projection lenses***, ***LED*** and ***heat sink***

Non-Tolerance Critical Components: Components which will continue to function correctly with slight disturbances in their alignment and relative position
These are: ***microfilm*** and ***reels***

These two sets of components, with different protectional requirements, are thus treated separately with two independent casings:



Inner Casing (tolerance critical components):

- Contains the components within the optical line, the PCB and the heat sink
- Rigid, guaranteeing correct alignment of the components

Outer Casing (non-tolerance critical components):

- Contains the inner assembly and the microfilm, reels and indexing knobs
- Relatively flexible, absorbing impact and twist

Therefore all external forces will be absorbed by the outer casing and not converted to relative movement within the inner assembly.

3.3 Materials and Processing

Polymers have been selected as the materials for the casing: UV resistant ABS for the outer housing and Acetal for the inner housing.

Polymers have been selected over aluminium or an alternative metal due to the reduced cost, weight and more appropriate mechanical properties. In particular the shock absorbing toughness of polymers is seen as a key protecting feature.

Injection moulding is the most appropriate processing route bringing with it the following advantages:

- Many features can be moulded directly into the part at no extra cost: For example, bosses, positioning features and strengthening ribs
- The unit cost of processing is very fast and low
- Snap fit joints can be easily incorporated into the mouldings

Both vacuum and reaction injection moulding have been considered with vacuum injection moulding being economical for all volumes greater than 107 units.

3.4 Design for Manufacture

Design for manufacture (DfM) enables:

- A product to be built efficiently
- Product changes to be carried out more easily
- Improved quality, reliability and robustness due to the use of appropriate manufacturing techniques

This project looks at two major DfM methods: minimising the number of parts and simplifying the way these are assembled.

3.4.1 Part Reduction

Part reduction has been achieved through a combination of the above analysis of component groups and a product simplification analysis found in Appendix D.

This has resulted in a reduction in the number of components from 86 in the Gamma to 48 of which 25% by number and 67% by cost contribute directly to the function of the projector. Further information on this is found in Appendix D.1 and Appendix E.1.

3.4.2 Design for Assembly

The assembly process has been constantly considered through the design process, in particular:

Minimisation of

- Parts – 48 compared to 90 on Gamma
- Sub assemblies – 1 compared to 5 on Gamma
- Repositioning or turning of parts – none apart from moving the subassembly into the main assembly
- Screw fixings

The assembly is now all carried out:

- in open areas
- from one direction
- in the direction of gravity

- Positioning features have also been built in

The assembly process is described in Appendix F along with a video in the handover directory.

A time and motion study was carried out on the assembly process according to MTM1 standards giving a result of 79 seconds for the assembly of each unit.

3.4.3 Injection Moulded Components

A major contributor to part reduction has been the introduction of injection moulded casings, which allow many features to be integrated into a single component.

The following were considered when designing the injection moulded components:

- Draft angles
- Constant thickness
- Identical top and bottom halves of casing requiring only one tool to be made

The identical top and bottom halves of the casing would, however, need some post-mould machining and thus it may be more economical to use a family mould instead.

Both options should be investigated.

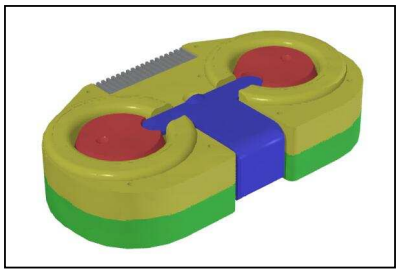
3.4.4 Snap Fit Joints

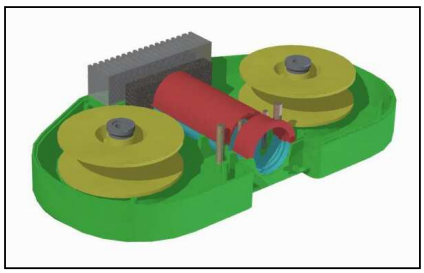
The simplification of mechanical joining processes, such as the elimination of screws by using snap fit joints, can greatly simplify an assembly process. The drawback is an adverse effect on the ease of disassembly and repair as well as (sometimes) a decrease in strength.

In the design concept, snap fit joints are recommended for the lens barrel assembly, but screws retained for the outer casings.

3.5 The Product

The concept shown illustrates all the above points, the main characteristics are described below.



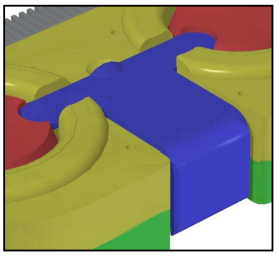


3.5.1 Protection

The casing of the product has been built for maximum protection against rough handling and usage:

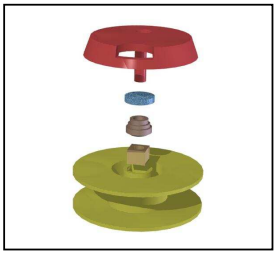
- Large, bulky external bosses protect all external components, creating a continuous protective envelope
- Two casing assemblies have been used with different mechanical properties for the different component requirements
- Rigid, but shock absorbing 3mm thick ABS external casing
- A lip on the edge of the outer casing acts a seal

3.5.2 Lens Cover and Locking Mechanism



A hinged lens cover which doubles as a locking mechanism for the reels and also a stand has been added.

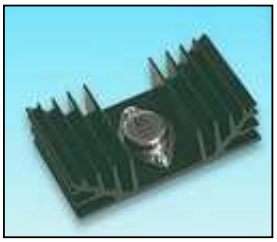
3.5.3 Microfilm Transfer System



The connection between the reel and the knobs has been simplified by using partially customised parts. A ratchet will fit directly into the reel, and the knob will then directly attach to the ratchet through a cover bush similar to that used on the Gamma design.

3.5.4 Lens Housing

The lens housing is based around that from the Fisher Price View Master Projector. This enables easier assembly, more accurate positioning and fewer parts.



3.5.5 Heat Sink

An off the shelf heat sink rated at 2.5 °C/W is used, this will give sufficient cooling when open to the air.

3.5.6 Focus Mechanism

A fixed focal length has been assumed. This is a result of the focal depth covering such a large area[7]. Tests would have to confirm this, if it was proved that an adjustable focus was necessary then a screw-based adjustable version is recommended similar to the Beta Prototype.

Four brass rods (which are not intended to turn) slotted into the outer casings are used to hold the microfilm in position.

3.5.7 Fixings

Fixings have not been fully considered and have not been included in the Solidworks models. It is anticipated that screws would be used to secure the outer casing and the inner casing to the outer casing and snap fit joints for the inner assembly.

3.6 Costing

A full bill of materials has been drafted and costed[8]. All parts are costed either from catalogue prices or estimates based on quotes for similar components and assemblies from manufacturing companies in China.

[7] Focus range = 3'-20' in Gamma
[8] Bill of materials available in Appendix G

The product cost including all components, assembly, packaging and delivery is shown in the table below.

Volume	*Cost per unit*
1,000	**$47.65**
5,000	**$28.45**
10,000	**$26.05**
25,000	**$24.61**
50,000	**$24.13**

The tooling cost amounts to $24,000 for the 6 injection moulded parts (top and bottom casing, cover and three piece inner lens assembly).

3.7 Component Sourcing and Assembly

It is recommended that all assembly and manufacture is outsourced to a manufacturing company based in a low cost location such as China. This greatly simplifies the supply chain and other management issues. This is particularly appropriate given *Design that Matters*' limited resources.

3.8 Manufacturing Conclusions

A concept design has been developed which can be produced in high volumes. The design makes use of:

- Injection moulded casings
- Off the shelf parts
- Manufacture in China
- Design for manufacture techniques

The design concept also introduces a number of new design innovations including a shock protection system and reel locking mechanism.

The design has been costed and can be produced for under $30 in volumes over 5,000 units. This is below the target cost of $50 and thus proves that an affordable version of the Kinkajou Microfilm Projector can be developed for production.

4. IMPROVING THE PRODUCT

When developing the next design iteration there is a wide scope for possible improvements both radical and subtle. This section of the report outlines some improvements that should be considered.

4.1 Solid State Memory

So far all Kinkajou designs have made use of microfilm as the storage media. This brings with it a number of possible problems:

- Expensive and centralised production (relies on access to a microfilm printer)
- Semi-permanent content, not easy to change by user
- Reliability of a mechanically controlled system
- Bulky storage
- Slow, linear indexing

All these problems could potentially be solved by the use of a solid state memory such as Flash which is potentially cheaper, smaller and easier to produce content for.

4.2 Integrated Power Supply

All research into adult literacy projects, including through *World Education* has concluded that a product solving power inadequacies must assume no power is available in any form. This includes car batteries. Research has also concluded that modular devices are undesirable due to security issues.

This presents a difficult issue but could be solved with an entirely integrated power supply.

The Freeplay Lifeline Radio[9] proves this is a possibility, running off solar and wind-up power. This is powered by a 3 cell 3.6V battery charged by a 5V 52mA solar panel. To power Kinkajou in its current form, a battery of around 7V would be

[9] See Lifeline case study in the handover directory

needed and a solar panel running at the same power but around 1000 sq mm would be required.

Therefore, three options are presented:

- Use the above defined battery and solar panel specifications; this may require a modular solar panel
- Look for a light source which would run from a lower power supply
- Look for a solar panel which would offer improved charging

With the current speed of advancement in LED technology, this could be an option in the near future.

4.3 Improved Image Contrast

As already outlined in Section 2, the market for Kinkajou could be dramatically expanded if it could be made to function in day light conditions by improving the contrast.

4.4 Local Manufacture

If Kinkajou was manufactured locally to where it was to be used, it would be appropriate to many more NGOs policies. It would also have much farther reaching benefits for developing world countries, boosting employment and providing people with new skills.

A Kinkajou that could be manufactured locally could be designed for small scale manufacture in just a few locations, with no need to limit production to this type of manufacture.

Alternatively, a particular location could be found for full manufacture of the Kinkajou. The second method would require much greater planning and care and may have political implications.

A third solution may be manufacture in a relatively developed location such as South Africa where all *Freeplay* Radios[10] are manufactured.

4.5 Changeable Microfilm

The introduction of easily changeable microfilm may increase the appeal of Kinkajou. However this would only be successful if it did not result in any significant increase in cost. A cartridge based version was suggested to possible customers, but the universal view was that the advantages were not significant enough to outweigh the potential increase in price.

4.6 Other Improvements

4.6.1 Rapid advance indexing

This could be either motorised or powered manually through a gear arrangement – the winding mechanism in the Lifeline Radio[11] is an example of stepping up the speed of manual power.

The addition of an indicator showing the position in the library would also be advantageous.

4.6.2 Handle

The addition of a handle would prevent accidental damage through picking Kinkajou up by fragile parts such as the power cables. At the same time the portability would be greatly improved

4.6.3 Adjustable projection angle

Creating an adjustable stand controlling the angle at which the image was projected would enable Kinkajou to be easily used from different levels. The addition of keystone adjustment could then improve the quality of an image projected at an angle by altering the lens arrangement.

[10] See Appendix A

5. CONCLUSIONS

5.1 Market Prospects

The Kinkajou Microfilm Projector has wide ranging appeal and the resulting potential to be successful in several different markets.

Adult literacy specifically, is estimated to have an attainable market of around 11,000 units.

The overall market could be many times larger than this if Kinkajou is adapted for new applications. These include opportunities in private education, adult training and health.

The lower than expected size of the adult literacy market beyond Mali is due to the problems which Kinkajou solves, not being as widespread as originally thought. Other issues within adult education currently receive prioritised attention over lighting and text book availability and there is also a current emphasis on locally designed and produced teaching material.

If however, initial use in Mali is a success, then the functionality of Kinkajou and the requirements of the wider market could converge.

5.2 Product Cost

Kinkajou can be produced for under $30 in numbers over 5,000.

5.3 Product Functionality

There is still a large scope for improving the functionality of Kinkajou. This will be very useful in order to penetrate markets beyond that of *World Education*'s.

[11] Freeplay Radio distributed solely by the Freeplay Foundation in the developing world

PART II

PROJECT DEVELOPMENT

The following chapter stands back from the project detail and attempts to take a critical but objective view of Kinkajou as a pioneering project for *Design that Matters*.

1. DISCUSSION

Through Kinkajou's evolution three characteristics have been identified as challenges which must be overcome to maintain the ongoing success of the project. These are inevitable issues in an organisation with the structure of *Design that Matters*: a not-for-profit based on the continuous learning of students.

I. Continuity of Development and Confirmation of Assumptions

Kinkajou has been developed by a series of teams working linearly on short term goals, passing work from one team to the next and relying on a thin layer of project management, shared by a large number of different projects.

If the transfer process from one team to the next is well managed, then this system can be a success. However, each team passes on assumptions, which if not challenged and confirmed with the inheriting team's new perspective, then the unproven and perhaps false assumptions can build up.

Continuity of development must however be maintained in order to avoid *reinventing the wheel* and reconfirming assumptions that have already been found to be true over and over again. The nature of a team based development process therefore must rely on a certain level of confidence in previous teams.

This issue requires a compromise to be taken. The following 2 characteristics however exacerbate the issue and make the situation more difficult to manage.

II. Projects Based on Learning

The learning experience of academic projects involves a cycle of making mistakes, identifying them, understanding them, correcting them and then passing on the experience and preventing it from happening again.

When this process is applied to real life projects, as Kinkajou has become, the circle becomes more critical. Before a new team takes on the next stage of development, lessons must be applied to the project in order to realign it with what should have happened or what is now most appropriate, given what has been learnt.

If a project is characterised as a learning experience it is also characterised by mistakes. This is constructive if the mistakes are corrected and the lessons passed on.

If short term planning and deadlines, which are the result of a project passed from team to team, prevent the full learning process, then the most important implementation and experience transfer stage can become neglected.

III. Performance Measurement and the Changing Balance of Goals

If we define measurement of success as the achievement of goals we can assess a project or company on how well it achieves its' goals.

Design that Matters could be considered to have two goals:

1. To help people in underprivileged communities through student projects
2. To leave a legacy with each student involved, encouraging them to pursue a career in this area

Every student who has contributed to the project and then graduated with a desire to pursue a career in helping underprivileged communities, makes Kinkajou a success according to goal two.

On the other hand, when Kinkajou matures and becomes a real world project with funding intended to help people in the developing world, rather than students in the US, the measure of success is more about achieving the first mentioned goal.

Therefore, to successfully measure the success of a *Design that Matters* project, the balance of goals must be defined.

As a project moves from a student project to a real world project, the balance of goals change and thus the project emphasis must also change. Therefore, the emphasis on learning must be sacrificed for hard decision making for the value of the project *not* the value of learning.

The legacy of learning and mistakes will remain with the project unless they are addressed. When the goal of the project is changed a process of rationalisation must occur which must question the reason behind every design decision thus far. This must be a priority and occur before the project is developed further.

2. CONCLUSIONS

If a project is to be realised in the real world, then its goals and measures of success must change. This involves a process of rationalisation to confirm a project is suitable for development or discover what must be changed to make it suitable.

The experience of viewing Kinkajou from a new perspective has, I believe, allowed me to gain a relatively neutral view on the projects' prospects. I have also gained views from the market which have been overlooked in the past. I believe that a number of issues have not been addressed in Kinkajous' evolution and as a result, if they are not resolved, the Kinkajou may not be the success it could be.

3. RECOMMENDATIONS

3.1 Project Management

A review of the process of project management should be carried out with specific attention to:

- How each individual student project fits into the overall project
- How the starting and handover points are defined
- How it is decided which assumptions and trains of thought should continue from one project to the next
- How design decisions and assumptions are regularly reviewed rather than just documented.

3.2 Assumption Confirmation

It is easy to overlook the process of confirming assumptions when the project is of the nature described above. In the process of continuing to develop Kinkajou, it is suggested that the following assumptions be confirmed:

The Microfilm Projector Concept

The concept of a microfilm projector has not changed since the proof that it worked in 2001; however this is a very specific solution to a more general problem. The research in Section 2 of the main report indicates that this specific solution has more of a niche market. There may be a better way of solving the problems than with microfilm and an LED, and it is suggested that this be investigated.

The Number of Slides Needed and the Implication this has on Content Storage

10,000 pages is the original number quoted for the volume storable on a Kinkajou, this is a result of the VHS tape being used in the Alpha prototype. In the Gamma prototype the same size reels are being used, allowing for 10,000 pages. *World Education* only requires 650 pages. Reels may therefore not be the most appropriate form of storage.

The Market for Kinkajou

The Kinkajou Microfilm Projector is a solution to two specific problems which *World Education* experience in Mali. The ability of the Kinkajou to solve these problems will be measured in the 6 month test in September 2004.

If Kinkajou is a niche product only needed in 1,700 classrooms in Mali and Guinea, then the value of the product is very different to if there is a world market for 50,000. The amount of effort invested in Kinkajou must be dependent on which of these scenarios is closest to the truth.

In the situation where the main goal is the education of students in the US this may not be an issue, but if the main beneficiary is intended to be the developing world - and this could either be 1,700 or 50,000 - then the value of investing in Kinkajou is an important issue.

The research in Section 2 of the main report suggests that the smaller market is nearer the truth and as such the value of investment must be assessed.

3.2 Six Month World Education Test

The 6 month test is aimed at assessing two issues:

- The pedagogical value of Kinkajou
- The ability of Kinkajou as a package to deliver the pedagogical function

Both of these issues must be proven for the Kinkajou to be manufactured in volume and distributed. However they must be proven not just for the test model, but on the actual model to be distributed. For the test to be of maximum benefit, the model tested must therefore be as similar to a volume produced model as possible.

The differences between the Gamma model and the design offered in Section 3 of the main report are deliberate: to avoid constraints imposed by continually improving an assumed design. Instead the concept is designed so that it can be efficiently manufactured in high volume and at low cost.

A conclusion from market research is that in any powered device, the power cannot be sourced locally. This includes the assumption that batteries are available locally and further, that modular batteries, even if supplied with the product, are undesirable.

The Gamma design is therefore different in at least two ways from the final model. There is limited time before the test begins, and little can be done to change the design. However, a test of this scale is not likely to be offered again, particularly if it raises doubts over the long term success of Kinkajou.

To make the test the success that it could be, the following is therefore recommended

- All assumptions that have affected what the Gamma prototype now is, should be thoroughly investigated and confirmed.
- The test must be designed exhaustively, based not what the *Gamma* can achieve or is intended to, but what the final solution can and should do in relation to the problem and the extended market.