UNIVERSITÄT BAYREUTH
Lehrstuhl Didaktik der Biologie

Dissertation

Bionik-Unterricht zwischen natürlichem Vorbild und technischer Anwendung

- Eine Studie zu Technikbegeisterung, naturwissenschaftlicher Motivation und langfristigem Wissenserwerb -

zur Erlangung des akademischen Grades

- Dr. rer. nat. -

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INHALTSVERZEICHIS

ABBILDUNGSVERZEICHNIS

Hinweis auf Geschlechtsneutralität:

Im Sinne des Leseflusses wird in folgender Arbeit nur die Form „Schüler" bzw. „Lehrer" verwendet und auf Doppelnennung „Schüler und Schülerinnen" und „Lehrer und Lehrerinnen" verzichtet. Wenn nicht explizit erwähnt, ist damit keine spezifische Zuordnung der Geschlechter gemeint. Es wird sich auf Personengruppen bezogen und nicht auf die einzelnen Geschlechter. In den Abschnitten, in denen auf Geschlechterunterschiede eingegangen wird, werden explizit die geschlechterspezifischen Bezeichnungen verwendet.

1 SUMMARY

Nowadays the subjects science, technology, engineering and mathematics (STEM) are often considered as boring or difficult to understand. Related individual interest scores often drop during school time, leading just few adolescents into technical or scientific careers. For this reason, educational programs need to cope with negative attitudes and to introduce positive images beyond a knowledge transfer.

For this purpose, we monitored perceptions of technology in 610 participants (students (n=369), teachers (n=116), university freshmen (n=125)): The individual interest in technology revealed highest scores for students. The social aspects showed an opposite trend, as teachers and university freshmen in terms of technology showed higher scores than students. Thus, technology apparently needs an early alignment with positive experiences to weaken rejection tendencies.

An interactive exhibition about bionics within the Zoo Nuremberg currently allows students to explore the world of bionics. An exhibition tour through the zoo makes bionics observable even on living animals. Based on these special opportunities, the bionics learning module addresses various bionic applications, such as the fin ray-effect and its bionic adaption of a robotic arm, the dolphins' communication (which is technically used in a tsunami pre-warning system) as well as the dolphin snout (which is used as a cap in tankers). The streamline shape of various animals and their adaption in the automotive industry were also discussed in the learning module.

In total, 369 sixth graders participated in the learning module by completing cognitive knowledge tests and being monitored regarding scientific motivation in combination with technology. The acquisition of short-term, medium-term and long-term knowledge was measured at five testing points, resulting in significant growth of knowledge over a full academic year. Students with a high interest in technology and more social aspects of technology showed better pre-knowledge levels. The results pointed to a significant increase in motivation directly after intervention, which disappeared again already six weeks after the intervention. A correlation of technology interest and the scientific motivation sub-scale self-confidence was shown small, but existing.

Consequently the learning module was able to promote content-related knowledge as well as scientific motivation of students and thus represents an opportunity to network different subject areas within an educational context. Therefore interdisciplinary teaching may support the various science subjects in order to bring technology and science into classrooms. In consequence, introducing bionics applications at an early stage might help preventing negative associations and providing optimal conditions for students` careers after school.

2 ZUSAMMENFASSUNG

Technik und Naturwissenschaften haben bei Schülern oftmals ein negatives Image und werden schlicht abgelehnt, da sie als schwer verständlich gelten und mit schwierigen Lerninhalten assoziiert werden. Das Interesse für Technik und Naturwissenschaften nimmt im Laufe einer Schullaufbahn häufig ab, weswegen nur wenige junge Erwachsene naturwissenschaftliche oder technische Laufbahnen einschlagen. Geeignete Unterrichtsprogramme sollten daher, neben der Wissensvermittlung, auf negative Vorstellungen eingehen und diese entsprechend positiv anreichern.

Um einen Überblick über das Technikinteresse und die Vorstellungen von Technik in verschiedenen Altersgruppen zu erhalten, wurden in der vorliegenden Arbeit das individuelle Technikinteresse und die sozialen Aspekte der Technik von 610 Teilnehmern erhoben (Schüler (n=369), Lehrer (n=116) und Studenten (n=125)): Dabei zeigte sich, dass das größte Technikinteresse (wenn auch schon auf niedrigem Niveau) bei der Altersgruppe der Schüler besteht. Bei den sozialen Aspekten zeigte sich ein gegenläufiger Trend. Lehrer und Studenten wiesen höhere soziale Kompetenzen in Bezug auf Technik auf, als dies bei Schülern der Fall war. Technik sollte folglich schon früh mit positiven Erfahrungen verbunden werden, um negative Assoziationen möglichst erst gar nicht entstehen zu lassen.

Eine interaktive Ausstellung im Tiergarten Nürnberg zum Thema Bionik erlaubt derzeit die Welt der Bionik kennenzulernen und zu erforschen. Angeschlossen an die Ausstellung ist ein bionischer Rundgang, der Bionik auch am lebenden Tier beobachtbar macht. Basierend auf diesen besonderen Möglichkeiten wurde ein Lernzirkel zum Thema Bionik entwickelt, welcher sich mit ausgewählten bionischen Themen, wie dem Fin Ray-Effekt und dessen bionischer Anwendung eines Greifarms in der Robotik beschäftigt. Im Zentrum des Lernzirkels standen bionische Phänomene im Wasser, wie die Delphin-Kommunikation, die technisch bei Tsunami-Frühwarnsystemen eingesetzt wird oder die Delphinschnauze, die als Bauvorlage für den Bugaufsatz bei Tankern verbaut ist. Auch die Stromlinienform verschiedener Tiere und deren Umsetzung in der Automobilindustrie wurden im Lernzirkel thematisiert.

Insgesamt nahmen an dem Lernzirkel 369 Schüler der sechsten Jahrgangsstufe teil. Der Lernzirkel war Grundlage von zwei Teilstudien, die zum einen kognitives Wissen und zum anderen naturwissenschaftliche Motivation in Kombination mit Technik erfassten. Der Erwerb von kurzfristigem, mittelfristigem und langfristigem Wissen wurde zu fünf verschiedenen Testzeitpunkten untersucht, mit dem Ergebnis eines signifikanten Lernzuwachses über ein gesamtes Jahr hinweg. Zusätzlich korrelierte das Technikinteresse signifikant mit dem Vorwissen in dem Maße, dass technikinteressierte Schüler mit höheren sozialen Werten auch mehr Vorwissen aufwiesen. Die naturwissenschaftliche Motivation zeigte lediglich direkt nach der Intervention einen signifikanten Anstieg, der allerdings sechs Wochen nach der Intervention nicht mehr vorhanden war. Außerdem zeigte sich eine Korrelation von Technikinteresse mit der naturwissenschaftlichen Motivation, auch wenn dieser Zusammenhang klein war.

Das Interventionsmodul Bionik konnte sowohl das inhaltsbezogene Wissen, als auch die naturwissenschaftliche Motivation von Schülern fördern und stellt damit eine Möglichkeit dar, wie man verschiedene Fachgebiete im schulischen Kontext vernetzen kann. Fächerübergreifender Unterricht könnte somit als Verknüpfungspunkt zwischen den verschiedenen Naturwissenschaften stehen, um den naturwissenschaftlichen Arbeitsweisen einen besseren Stellenwert in der Schule einzubringen. Werden Schüler frühzeitig mit Technik und Naturwissenschaften in Kontakt gebracht, könnte die Bildung negativer Assoziationen verhindert und somit die Einstellung zu Technik und Naturwissenschaften langfristig verändert werden.

3 AUSFÜHRLICHE ZUSAMMENFASSUNG

3.1 Einleitung

Technik und neue Technologien werden oftmals mit Risiken und Gefahren assoziiert (Ardies, De Maeyer, & David Gijbels, 2013). Auch das Interesse für Technik nimmt häufig im Laufe einer Schullaufbahn ab (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). Der gleiche Trend lässt sich leider auch in den Naturwissenschaften feststellen, indem häufig eine Abnahme des Interesses und der Motivation in den Naturwissenschaften zu verzeichnen ist (Osborne, Simon, & Collins, 2003). Viele Studien belegen ein ausgesprochen geringes Interesse von Schülern an Naturwissenschaften (Krapp & Prenzel, 2011; Merzyn, 2008), obwohl die Naturwissenschaften immer mehr Aufmerksamkeit erhalten (Ardies et al., 2015) und auch eine immer größere Rolle im Leben der Schüler spielen (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011). Daher ist es besonders wichtig, die naturwissenschaftliche Grundbildung zu fördern, um die Schüler bestens auf das spätere Leben vorzubereiten, sei es in Diskussionen um Naturwissenschaften, bei technischen Phänomenen oder in der Arbeitswelt (DeBoer, 2000).

Da die Biologie -unter den Naturwissenschaften- das größte Interesse der Schüler verzeichnen kann (Merzyn, 2008), könnten negative Stigmatisierungen durch die Vernetzung von Biologie und den anderen Naturwissenschaften abgebaut und in ein positives Bild umgewandelt werden. Vor allem die von Mädchen und jungen Frauen beschriebene Biologiebegeisterung (Baram-Tsabari & Yarden, 2011) könnte genutzt werden, um auch deren Interesse in anderen Naturwissenschaften und der Technik zu fördern. Aufgrund dessen wurde die Bionik als interdisziplinäres Themenfeld für die vorliegende Studie ausgewählt und eine Bildungsmaßnahme entworfen, die sowohl auf Einstellungen und Interessen in Bezug auf Technik und Naturwissenschaften eingeht, als auch versucht diese nachhaltig durch inhaltsbezogenes Wissen und adäquate Lernmethoden zu beeinflussen.

Bionik ist eine Wissenschaft, die die Teilbereiche Technik und Biologie vereint. Die Biologie bietet dabei die Vorbilder, die Technik dagegen setzt die Prinzipien und Ideen in technische Anwendungen um (Nachtigall & Wisser, 2013). Im Tiergarten Nürnberg wurde 2014 das *Bionicum* mit der Besucherausstellung *Ideenreich Natur* eröffnet, in der die Besucher die Bionik erforschen und der dahinter stehenden Technik ein Stück näher kommen können. In der interaktiven Ausstellung kann man Experimentieren, Anfassen, Mitmachen, Staunen und sich von der Faszination der Bionik inspirieren lassen. Es werden vielfältige Themen wie die Hafttechnik des Geckos, selbstschärfende Messer, verschiedene Haut-Effekte, selbststrukturierende Materialien und sogar ein tanzender Roboter vorgestellt. Die Besucherausstellung beinhaltet zudem einen „bionischen" Rundgang und erstreckt sich damit über den gesamten Tiergarten. Der „bionische" Rundgang führt an verschiedenen Tieren vorbei, die Vorbild für bionische Anwendungen in der Technik sind. An den einzelnen Stationen des Rundganges können die Besucher das Naturvorbild direkt am Originalobjekt begutachten und auf das technische Phänomen übertragen, welches in Abbildungen, Hörstationen und Informationstafeln erklärt wird. Mit dieser Vernetzung wird im Tiergarten die Verbindung von Technik und Naturwissenschaften am lebenden Objekt hergestellt.

Eine Zusammenarbeit des *Bionicums* mit der Biologie Didaktik an der Universität Bayreuth hat das Potential Schulen und die didaktische Forschung in die Ausstellung „Ideenreich Natur" einzubringen, denn die Bionik als neue Fachrichtung soll Einzug in die Schule erhalten. Im Gymnasium wird die Bionik explizit in Jahrgangstufe sechs im Fach Natur und Technik integriert, in der Realschule ist die Bionik leider noch nicht im Lehrplan verankert (ISB, 2004).

Die Bionik könnte als Verknüpfungspunkt zwischen den Naturwissenschaften und der Technik stehen, weswegen der Schwerpunkt der vorliegenden Arbeit auf der Evaluation der Unterrichtsintervention zum Thema Bionik liegt. Besonderes Augenmerk wird dabei auf die Verknüpfung von Technik mit inhaltsbezogenen Wissen und der Motivation gegenüber Naturwissenschaften gelegt.

3.2 Theoretischer Hintergrund

3.2.1 Bionik - eine neue alte Wissenschaft

„Der menschliche Schöpfergeist
kann verschiedene Erfindungen machen (…),
doch nie wird ihm eine gelingen, die schöner,
ökonomischer oder geradliniger wäre als die der Natur,
denn in ihren Erfindungen fehlt nichts und nichts ist zu viel“.

Leonardo da Vinci

Der menschliche Erfindergeist hat von Beginn an durch das Beobachten in der Natur gelernt. Bereits um das Jahr 1500 begann Leonardo da Vinci mit der Konstruktion von Flugapparaten, nachdem er sich Inspiration aus der Natur geholt hatte (Nachtigall & Wisser, 2013). Auch Otto Lilienthal beschäftigte sich mit dem Traum vom Fliegen. Er ließ sich vom Flug der Störche inspirieren und konstruierte auf dessen Grundlage ein Erklärungsmodell, welches er in einem Gleitflugapparat realisierte (Speck, Speck, Neinhuis, & Bargel, 2012). Diese beiden Wissenschaftler galten als Wegbereiter der Bionik, auch wenn das heutige Forschungsgebiet damals noch keinen eigenen Namen trug.

Der Begriff **Bionik** wird im Deutschen gerne aus **Bio**logie und Tech**nik** zusammengesetzt, was jedoch nicht der Historie entspricht (Nachtigall & Wisser, 2013). Die Herkunft des Wortes *Bionik* liegt im Englischen und wurde erst später „eingedeutscht“. Im Jahre 1960 fand in den USA ein Kongress namens „Bionics symposium“ statt, bei dem der Begriff *Bionics* das erste Mal verwendet wurde, weswegen dieser Kongress als Geburtsstunde des Wortes *Bionics* gilt (Nachtigall & Wisser, 2013). Die Wissenschaftler und Techniker folgen genau, wie die Vorreiter der Bionik, den Weg der Natur und deren Lösungsfindung.

Die Bionik wird heute definiert als „Technische Umsetzung von Prinzipien der Natur“ (Nachtigall, 1998; S.60) oder als „Lernen aus der Natur für die Technik“ (Nachtigall, 2010; S.144). „Bionik ist ein typisches Grenzgebiet, in dem sich Biologie und Technik überschneiden“ (Nachtigall, 2010; S.35).

Die Vernetzung von Technik und den Naturwissenschaften könnte sich für die Begeisterungsfähigkeit der Menschen zu Bionik positiv auswirken, denn die Bionik liefert viele innovative Lösungsansätze, die ihren Ursprung in der Natur haben. Es werden immer mehr Erfindungen gemacht, die bionischen Ursprungs sind. Der Lotus-Effekt, welcher eine sich selbstreinigende Oberfläche aufweist, ist eines der bekanntesten bionischen Beispiele (Neinhuis & Barthlott, 1997). Ein anderes Beispiel ist die Struktur der Hai-Haut, welche den Widerstand in Wasser minimieren kann, was unter anderem in der Luftfahrt eingesetzt wird, um auch dort den Widerstand zu reduzieren (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe, 1997). Bionik könnte einen Verknüpfungspunkt herstellen, der die Menschen begeistert und Interesse hervorruft.

3.2.2 Technikbegeisterung

Technik ist aus unserer heutigen Welt nicht mehr wegzudenken (Ardies et al., 2015). Kaum ein elektronisches Gerät funktioniert ohne technisches Know-how. Die junge Generation wächst in einer Welt auf, die von sozialen Medien und Kommunikationstechnologien geprägt wird (O'Keeffe & Clarke-Pearson, 2011). Die meisten Jugendlichen assoziieren Technik mit Computern und modernen Anwendungen (Rennie & Jarvis, 1995). Vor allem moderne Geräte wie Handys oder Fernseher erfreuen sich in Bezug auf Technik immer größerer Beliebtheit (Solomonidou & Tassios, 2007). Insgesamt gibt es aber ein breites Spektrum an Vorstellungen über Technik, die komplexer werden, je älter die Schüler sind (Rennie & Jarvis, 1995).

Trotzdem werden mit Technik oftmals langweilige Themen oder schwierige Lerninhalte in Verbindung gebracht (Ardies et al., 2013). Deswegen ist es von besonderer Bedeutung, dass die Schüler frühzeitig positive Erfahrungen sammeln können, um diese Scheu abzulegen (Akpınar, Yıldız, Tatar, & Ergin, 2009). Vor allem negative Erfahrungen können zu negativen Attributionen führen, welche später oftmals nicht oder nur schwer korrigiert werden können (Simpson & Oliver, 1990).

Es wurde festgestellt, dass die positiven Einstellungen im Laufe der Schulzeit oftmals sinken (George, 2006). Dieses Phänomen betrifft vor allem Mädchen und junge Frauen, die schon oftmals im Vorschulalter weniger Technikinteresse aufweisen (Rennie & Jarvis, 1995). Schon das Spielzeug im Vorschulalter ist Geschlechter stereotypisiert (Brown, 1993). Auch die stereotype Rollenverteilung der Eltern wird in der frühen Kindheit oftmals angenommen (Eccles & Jacobs., 1990). Die Geschlechterunterschiede ziehen sich durch die gesamte Schulzeit (Riegle-Crumb, Farkas, & Muller, 2006) und sind auch im späteren Arbeitsleben häufig noch existent (Beede, Julian, & Langdon, 2011). Baram-Tsabari & Yarden (2011) zeigten, dass Geschlechterunterschiede in der frühen Kindheit noch gering sind und erst am Ende der Sekundarstufe voll ausgeprägt werden.

Das könnte ein Ansatzpunkt für unterrichtliche Bemühungen sein, denn je früher man in den technischen Sektor einsteigt, desto besser könnte dem Auseinanderentwickeln der Geschlechter entgegengewirkt werden. Wenn man die Attributionen und Interessen seiner Schüler in Bezug auf Technik kennt, kann man adäquates Lernmaterial und Lernanforderungen generieren und den Vorwissensstand in seine unterrichtlichen Vorüberlegungen einbeziehen, wovon vor allem die Mädchen profitieren könnten.

Aufgrund dessen wurde in der vorliegenden Studie das Technikinteresse und die sozialen Aspekte der Technik, welche beides Sub-Skalen des Technology Questionnaires sind, von Schülern, Lehrer und Studenten erhoben (Harding & Rennie, 1992). Nicht nur die Begeisterung für Technik, sondern auch die Begeisterung für Naturwissenschaften generell, sollte im Fokus der schulischen Bemühungen stehen.

3.2.3 Naturwissenschaftliche Grundbildung und Motivation, Naturwissenschaften zu erlernen

Auch die Naturwissenschaften sind häufig negativ stigmatisiert, was Studien durch ein geringes Interesse an Naturwissenschaften bestätigen (Krapp & Prenzel, 2011; Merzyn, 2008). Die Biologie ist die Naturwissenschaft, die im Vergleich zu den anderen am wenigsten abgelehnt wird (Merzyn, 2008). Kleine Kinder beispielsweise zeigen hohes Interesse an Dingen, die sich aktiv bewegen, sprich vor allem an Tieren (Gropengiesser, 2008). Besonders Mädchen und junge Frauen zeigen größeres Interesse für Biologie als für Technik und Physik (Baram-Tsabari & Yarden, 2011). Mit Hilfe der Biologie könnte man das Interesse junger Menschen, vor allem von Mädchen, einfangen und sie so für Naturwissenschaften begeistern und deren Grundbildung fördern.

Die naturwissenschaftliche Grundbildung (scientific literacy) ist eines der wichtigsten Ziele, die ein Bildungssystem beinhaltet, um junge Menschen an die Naturwissenschaften heranzuführen (ISB, 2004). Die naturwissenschaftliche Grundbildung wird definiert als „Fähigkeit, naturwissenschaftliches Wissen anzuwenden, naturwissenschaftliche Fragen zu erkennen und aus Belegen Schlussfolgerungen zu ziehen, um Entscheidungen zu verstehen und zu treffen, welche die natürliche Welt und die durch menschliches Handeln an ihr vorgenommenen Veränderungen betreffen“ (Killermann, Hiering, & Starosta, 2011; S.60). Das naturwissenschaftliche Verständnis wird benötigt, um den immer größer werdenden Einfluss der Naturwissenschaften auf das alltägliche Leben zu bewerkstelligen (DeBoer, 2000). Auch bei Entscheidungen, die die Naturwissenschaften peripher betreffen, kann die Grundbildung in naturwissenschaftlichen Bereichen hilfreich sein (Miller, 1983). Menschen mit naturwissenschaftlicher Grundbildung fühlen sich oftmals kompetenter in alltäglichen Belangen, die Naturwissenschaften betreffen (Laugksch, 2000). Aufgrund dessen sollte das Ziel im Bildungsberiech der Naturwissenschaften die naturwissenschaftliche Grundbildung sein. DeBoer (2000) hält dieses Ziel für das Bedeutendste in Bezug auf die Vorbereitung des späteren Arbeitslebens. Dieses Ziel sollte vor allem in der Schule realisiert werden, indem die Motivation, Naturwissenschaften zu erlernen, gesteigert werden sollte.

Die naturwissenschaftliche Motivation kann als ein innerer Zustand, der das Verhalten, Wissenschaften erlernen zu wollen, weckt und erhält, definiert werden (Glynn et al., 2011). Motivation generell kann unterteilt werden in intrinsische und extrinsische Motivation (Deci & Ryan, 1985): Bei der intrinsischen Motivation wird eine Sache aus einem inneren Willen heraus durchgeführt, die extrinsische Motivation ist vornehmlich zielorientiert und wird von äußeren Einflüssen geleitet. Für das Erreichen von Zielen ist sowohl die intrinsische als auch die extrinsische Motivation vonnöten, als Antrieb hierfür wird ein Streben nach Kompetenz, sozialer Eingebundenheit und auch Selbständigkeit angegeben (Ryan & Deci, 2000). Motivation ist zudem abhängig von der Selbstwirksamkeit (self-efficacy) der Schüler, die die Überzeugung der Schüler zeigt, ob sie eine Aufgabe erfolgreich meistern können (Bandura, 1986). Auch das Selbstkonzept, das die Schüler von sich haben, wird oftmals als eine Variable der Motivation gesehen (Benabou & Tirole, 2002).

Deswegen sollte bei unterrichtlichen Bemühungen nicht nur das Wissen im Vordergrund stehen, sondern auch das Lernen für das Leben im naturwissenschaftlichen Kontext (Vedder-Weiss & Fortus, 2011), bei dem die naturwissenschaftliche Motivation integriert wird (Glynn et al., 2011). Um adäquate Lernprogramme für die naturwissenschaftliche Grundbildung entwickeln zu können, ist es hilfreich, das Level der Motivation der Schüler vorab zu kennen.

In der vorliegenden Studie wurde die naturwissenschaftliche Motivation mittels des Science Motivation Questionnaires II und dessen Sub-Skalen Intrinsische Motivation, Noten-Motivation und Selbstwirksamkeit überprüft und deren Veränderung in Bezug auf die Intervention Bionik verfolgt (Glynn et al., 2011). Wenn der Lehrer Motivationsdefizite seiner Schüler kennt, kann er diesen frühzeitig mit angepassten Lerninhalten und Methoden entgegenwirken, um den Unterricht optimal zu gestalten und möglicherweise auch eine Motivationssteigerung zu generieren.

3.2.4 Wissenserwerb in Bezug zu Kompetenzen

Unterrichten ist eine sehr komplexe Aufgabe, die viele verschiedene Arten von Wissen, wie das inhaltliche, pädagogische und das technische Wissen, beinhaltet (Mishra & Koehler 2006). Deswegen ist eines der zentralen Konzepte das Unterrichten in Bezug auf Wissen, wobei traditionell das inhaltsbezogene Wissen die größte Rolle in den Klassenzimmern spielt, welches als Organisation einer Fülle an Information verstanden werden kann (Shulman, 1986).

Wissen darf aber nicht im alleinigen Fokus der unterrichtlichen Bemühungen stehen, denn es sollte sich von einem reinen „Input" zu einem „Output" bewegt werden, hin zu Kompetenzen, Werthaltungen, Einstellungen und anderen Wissensstrukturen (Berck & Graf, 1999). Für die Erreichung dieses Ziels wurden zum Curriculum in Deutschland fachbezogene Bildungsstandards hinzugefügt, die angeben, was der Durchschnitt der Schüler an bestimmten Punkten (z.B. Deutsch am Ende der Primarstufe und Biologie am Ende der Sekundarstufe I) ihrer schulischen Laufbahn wissen sollte (KMK, 2012).

Um eine bessere Strukturierung zu erhalten, wurden Kompetenzen erstellt. Unter diesen Kompetenzen versteht man „die bei Individuen verfügbaren oder durch sie erlernbaren kognitiven Fähigkeiten und Fertigkeiten, um bestimmte Probleme zu lösen, sowie die damit verbundenen motivationalen, volitionalen und sozialen Bereitschaften und Fähigkeiten um, die Problemlösungen in variablen Situationen erfolgreich und verantwortungsvoll nutzen zu können" (Weinert, 2001; S.27). Diese Kompetenzen werden unterteilt in konzeptbezogene Kompetenzen, die den Kompetenzbereich Fachwissen beinhalten, und prozessbezogene Kompetenzen, bei denen die Kompetenzbereiche Erkenntnisgewinnung, Kommunikation und Bewertung im Vordergrund stehen (Berck & Graf, 1999). Der Kompetenzbereich Fachwissen wird zudem in drei Basiskonzepte unterteilt (System, Entwicklung, Struktur und Funktion). Zu jedem dieser Kompetenzbereiche wurden einzelne Standards festgesetzt.

Der Kompetenzbereich Fachwissen und das zugehörige Basiskonzept Struktur und Funktion „legt die Grundlage für das Verständnis der Funktion und Entwicklung von Biosystemen" durch „das Erfassen, Ordnen und Wiedererkennen von Strukturen" fest (KMK, 2004; o.S.). Dieses Basiskonzept Struktur und Funktion ist nahezu bei allen bionischen Themen gegeben, denn die Struktur eines biologischen Phänomens bedingt auch immer eine technische Funktion. Auch die prozessbezogenen Kompetenzen wie die Kommunikation, bei der die Kompetenz geschult wird, wie die Schüler an ihre Information gelangen, und die Bewertungskompetenz können mit Hilfe bionischer Themen geschult werden.

Um die Kompetenzorientierung noch besser in den Schulalltag integrieren zu können, wurde in Bayern der neue Lehrplan PLUS entworfen, der die Verflechtung von Kompetenzen und Inhalten garantieren soll. Es wird nicht nur der Inhalt jedes Themas im Lehrplan gestellt, sondern auch konkrete Anwendungssituationen (ISB, 2017).

Für die Bionik beispielsweise wird die Kompetenzerwartung folgendermaßen formuliert (ISB, 2017; o.S.): „Die Schülerinnen und Schüler leiten aus den Erkenntnissen über den Bau von Fortbewegungsstrukturen bei Wirbeltieren Konstruktionsmöglichkeiten zur technischen Unterstützung menschlicher Mobilität ab". Der dazu bereitgestellte Inhalt im Lehrplan PLUS lautet: „Bionik: z. B. Schiff, Flugzeug" (ISB, 2017; o.S.). Damit wird von einer reinen Wissensvermittlung hin zu einem Mehr an Vermittlung durch Kompetenzen gegangen.

In der vorliegenden Studie wurde versucht, sowohl die Inhalte als auch Kompetenzen zu fokussieren und den Schülern mehr als reines Wissen zu vermitteln. Die Überprüfung erfolgte anhand dessen, welchen Inhalt die Schüler in der Intervention mitgenommen haben, da es sich sehr schwierig gestaltet, Kompetenzen wie Kommunikation oder Erkenntnisgewinnung zu überprüfen. Für die Überprüfung wurde ein eigens entwickelter Wissensfragebogen eingesetzt, wobei vor allem der langfristige Wissenserhalt nach einem Jahr von Interesse war. Das Wissen über Bionik könnte eine Möglichkeit darstellen, die Naturwissenschaften und die Technik mit positiven Bildern anzureichern.

3.3 Ziele und Fragestellungen der Teilarbeiten

Die vorliegende Arbeit widmet sich dem Technikinteresse und der Bionik, wobei im Rahmen eines exemplarischen Unterrichtsmoduls für die Sekundarstufe (Jahrgangsstufe sechs) dabei auf den Wissenserwerb und die naturwissenschaftliche Motivation eingegangen wird. Um den momentanen Stand des Technikinteresses zu erfassen, wurde eine Vorstudie zum Technikinteresse und sozialen Aspekten der Technik von Schülern, Lehrern und Studenten erhoben. Dieses wurde anschließend in die Konstruktion des Stationenlernens Bionik mit eingearbeitet und dabei die Beziehung von langfristigem Wissenserhalt nach einem Jahr und der naturwissenschaftlichen Motivation untersucht (siehe Abbildung 1).

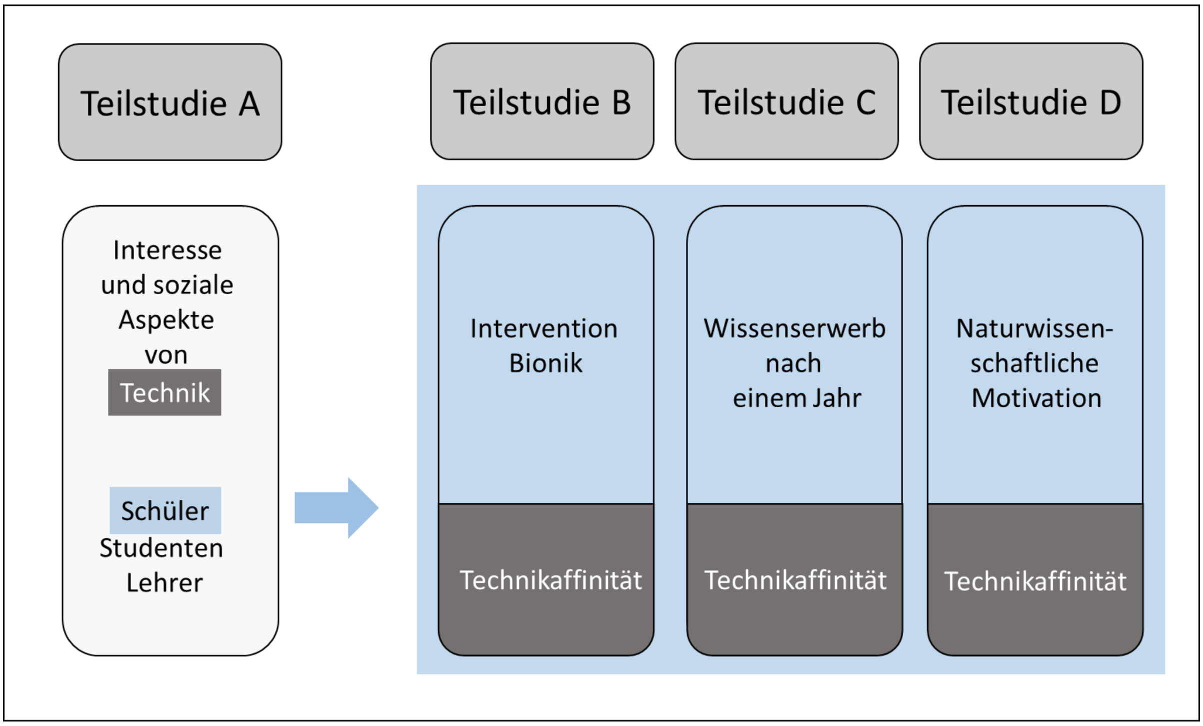

Abbildung 1: Übersicht über die Teilstudien der Gesamtintervention

Teilstudie A

In Teilstudie A soll die Einstellung gegenüber Technik untersucht werden, denn in der Literatur besteht oft die Annahme, dass Technik mit Langeweile assoziiert wird (Ardies et al., 2013). Für die Erfassung des Status quo zu Technikeinstellungen wird in der vorliegenden Studie das Messinstrument des Technik-Fragebogens (Technology Questionnaire Teil B) von Harding & Rennie (1992) verwendet. Hierfür werden verschiedene Gruppen ausgewählt, um einen Altersquerschnitt zu erhalten. Die jüngsten Teilnehmer sind Schüler aus der Sekundarstufe (Jahrgangsstufe sechs), gefolgt von Studenten in den ersten Semestern und schließlich die älteste Gruppe, die Lehrer. Zusätzlich sollen Geschlechterunterschiede untersucht werden.

Die konkreten Fragestellungen der Teilstudie A lauten:

1. Ist der Technology Questionnaire für den deutschsprachigen Raum anwendbar?
2. Ist der Technology Questionnare mit seinen zwei Faktoren (Technikinteresse und soziale Aspekte der Technik) ein geeignetes Instrument für verschiedene Altersgruppen?
3. Gibt es zum Technikinteresse und den sozialen Aspekten Unterschiede zwischen den Altersgruppen?

4. Gibt es bezüglich des Technikinteresses und der sozialen Aspekte Geschlechtereffekte in den einzelnen Altersgruppen?

Teilstudie B

In Teilstudie B war das Ziel, einen adäquaten Lernzirkel rund um das Thema Bionik zu erstellen. Die Schüler sollen dabei die generelle Vorgehensweise von Bionikern und Naturwissenschaftlern kennenlernen. Nach dieser Intervention sollen die Schüler in der Lage sein, bionische Beispiele zu identifizieren und einige ausgewählte bionische Beispiele, wie die des Fin-Ray Effektes oder die Bionik der Delphinschnauze, kennen. Das Modul Bionik ist dabei in verschiedene Sub-Module unterteilt: in das Arbeiten und Lernen im Seminarraum (Seminarraum-Modul) und in das Lernen am Originalobjekt (Aquarium-Modul). Die Schüler sollen nicht möglichst viele Beispiele auswendig lernen, sondern das Prinzip und die Mechanismen des naturwissenschaftlichen Feldes der Bionik erkunden und erkennen, dass Bionik ein sehr großes Themenfeld ist, welches ihnen in ihrem alltäglichen Leben begegnet. Zudem soll durch dieses Modul das Technikinteresse und die naturwissenschaftliche Motivation gesteigert werden.

Teilstudie C

In Teilstudie C liegt der Fokus auf dem Erwerb von Wissen im Themengebiet Bionik. Dabei sollen der kognitive Lernerfolg mittels eines selbst entwickelten Wissensinstruments überprüft werden. Durch die Teilnahme am Modul Bionik werden kurz- und langfristige Effekte in Bezug auf den Lernerfolg untersucht. Zusätzlich soll vor allem der langfristige Wissenserwerb nach einem Jahr überprüft werden. Das Vorwissen soll zudem in Bezug zum Technikinteresse und den sozialen Aspekten von Technik gesetzt werden.

Die konkreten Fragestellungen der Teilstudie C lauten:

1. Sind Veränderungen des Wissens im Gesamt-Modul und den Sub-Modulen nach der Intervention zu verzeichnen?
2. Sind Langzeiteffekte nach einem Jahr in Bezug auf Wissen vorhanden?
3. Kann eine Verbindung zwischen Wissen und Technikinteresse bzw. den sozialen Aspekten von Technik hergestellt werden?

Teilstudie D

Der Schwerpunkt der Teilstudie D liegt auf der naturwissenschaftlichen Motivation bzw. der Motivation, Naturwissenschaften zu erlernen. Das Erlernen von Naturwissenschaften und deren Motivation nimmt im Laufe der Adoleszenz immer mehr ab (Vedder-Weiss & Fortus, 2011). Um dem entgegen zu wirken, soll untersucht werden, ob man mit einer Intervention zum Thema Bionik die naturwissenschaftliche Motivation fördern könnte. Für die Erfassung der Motivation der Schüler wird in der vorliegenden Studie der Science Motivation Questionnaire II eingesetzt, überprüft und anschließend ausgewertet. Die Verbindung von Biologie und Technik, die die Bionik herstellt, soll eine Möglichkeit darstellen, die Motivation zu fördern. Die Verbindung zwischen Motivation für Naturwissenschaften und Technikinteresse soll in Bezug auf die Interdisziplinarität näher betrachtet werden.

Die konkreten Fragestellungen der Teilstudie D lauten:

1. Ist der Science Motivation Questionnaire auch für jüngere Altersstufen geeignet, um die naturwissenschaftliche Motivation zu überprüfen?
2. Beeinflusst eine eintägige Interventionsstudie zum Themengebiet Bionik die Motivation zu Naturwissenschaften?
3. Sind Geschlechterunterschiede im Bezug zur naturwissenschaftlichen Motivation zu verzeichnen?
4. Gibt es eine Verbindung zwischen naturwissenschaftlicher Motivation und Technikinteresse bzw. sozialen Aspekten von Technik?

3.4 Das Interventionsmodul Bionik am außerschulischen Lernort Zoo (Teilstudie B)

Die Inhalte des Interventionsmodul Bionik wurden gemäß der Inhalte des bayerischen Lehrplans ausgewählt (ISB, 2004). Der Unterricht wurde immer von demselben Lehrer und demselben Tutor durchgeführt und zuvor in einer Pilotstudie mit Studenten und Schülern getestet.

Die Intervention fand im Tiergarten Nürnberg statt und dauerte fünf Schulstunden (225 Minuten), die in verschiedene Phasen unterteilt wurden: eine Einführungsphase, zwei Modulphasen und eine Abschlussphase (siehe Abbildung 2).

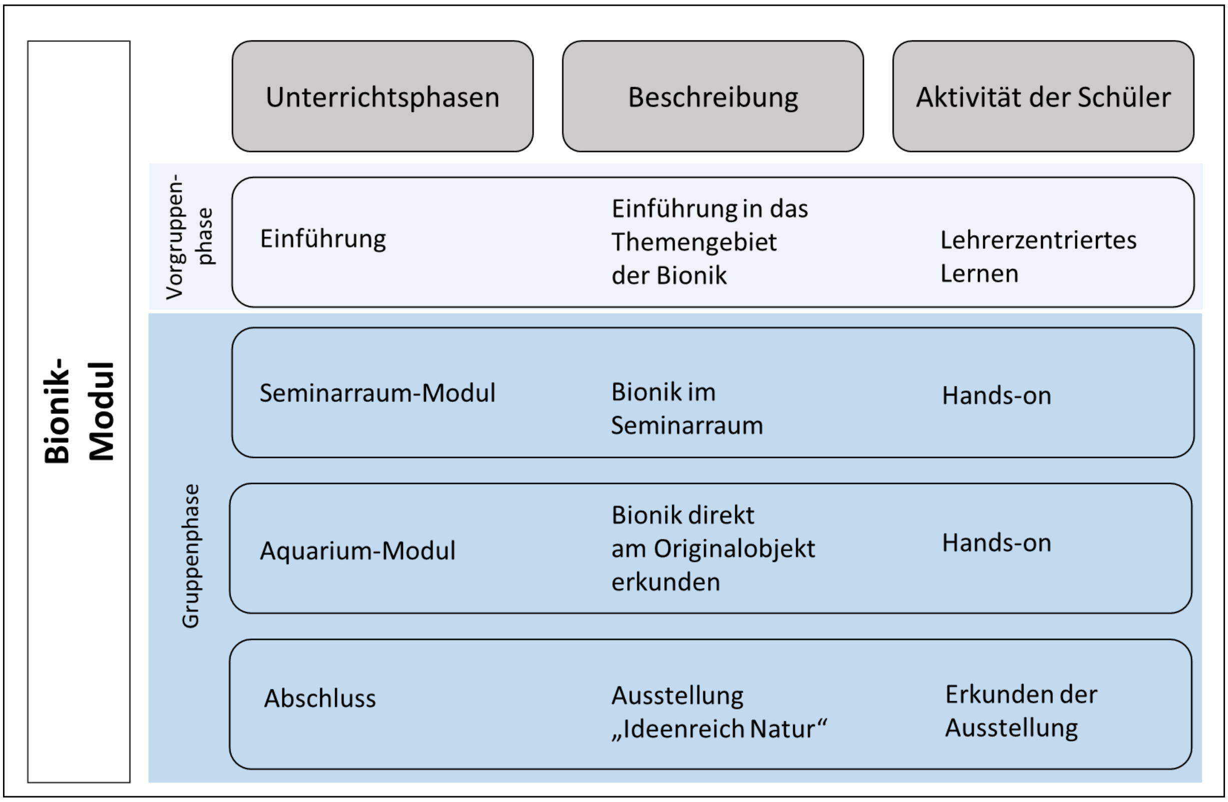

Abbildung 2: Übersicht über das Interventionsmodul Bionik

3.4.1 Einführungsphase

Um gleiches Vorwissen am Anfang des Tages zu garantieren, gab es eine lehrerzentrierte Vorgruppenphase zum Thema *„Was ist Bionik?"*, in der Bionik eingeführt wurde und ausgewählte Beispiele und Grundkenntnisse der Bionik, der Biologie und der Technik vermittelt wurden.

3.4.2 Gruppenphase

In den folgenden Modulteilen arbeiteten die Schüler in Gruppen, bestehend aus drei bis vier Schülern. Die kooperativen Lernformen waren selbsterklärend mit hands-on Materialien, wobei die Schüler am Anfang ein Arbeitsheft mit allen nötigen Anleitungen und Informationen bekamen (siehe Anhang 1-4). Dieses Arbeitsbuch half ihnen beim Stationenlernen durch die einzelnen Aufgaben und gab Anweisungen und Tipps.

Die Gruppenphase wurde unterteilt in zwei Sub-Module und ein Abschluss-Modul, da die Module an unterschiedlichen Orten im Tiergarten abgehalten wurden. Das Seminarraum-Modul, welches in einem speziellen Klassenzimmer im Tiergarten stattfand. Das Aquarium-Modul, welches direkt im Blauen Salon (Delphinarium, Aquarium) des Tiergartens Nürnberg eingegliedert war, und das Abschluss-Modul, welches sich in der Ausstellung „Ideenreich Natur“ befand.

3.4.2.1 Seminarraum-Modul

Im Seminarraum-Modul durften die Schüler verschiedene Stationen rund um das Thema Bionik bearbeiten (siehe Abbildungen 3a & b).

Abbildung 3a & b: Lernen im Seminarraum-Modul (Landesamt für Umwelt, 2015)

Bei der Station *Bionik: Erfindungen der Natur* wurden verschiedene prominente Beispiele der Bionik vorgestellt (Lotus-Effekt, Gecko-Haftsystem, Mechanismus des Klettverschlusses, Winglets, hexagonale Waschmaschinentrommel, selbstschärfende Messer, Architektur des Eifelturms). Hierfür mussten die Schüler Bilder von Naturvorbildern und bionischer Anwendungen in der Technik kleinen Textabschnitten zuordnen. Die Station *Schneller mit dem Strom* beschäftigte sich mit der Stromlinienform verschiedener Objekte. Hierzu führten die Schüler ein Experiment mit verschiedenen Formen (Kugel, Würfel, Quader, Stromlinienform und anderen) durch, um die Eintauchtiefe in einen Glaszylinder und somit die Schwimmeigenschaften der einzelnen Formen zu beurteilen. Hierbei zeigte die Stromlinienform die besten Ergebnisse. Eine weitere Station beschäftigte sich mit dem *Fin Ray-Effekt*, welcher sich in den Schwanzflossen von Fischen zeigt. Hierfür bekamen die Schüler Modelle, die das Prinzip des Effektes verdeutlichten. Zusätzlich lernten die Schüler die bionische Anwendung eines Greifers mit Fin Ray-Effekt kennen. Die letzte Station *Hautsache* beschäftigte sich mit verschiedenen Hauttypen und deren Anpassung ans Wasser. Die Schüler lernten in dieser Station zudem die Bionik des Hai-Haut-Effektes kennen. Im Seminarraum gab es zudem eine Zusatzstation *Bedrohung Mensch* für sehr schnelle Schüler, die sich mit dem Schutz der Delphine beschäftigte.

3.4.2.2 Aquarium-Modul

Im Aquarium-Modul standen die echten Tiere Großer Tümmler (*Tursiops truncatus*), Nagelmanati (*Trichechus manatus*), Schwarzer Pacu (*Colossoma macropomum*) und der Seelöwe (*Neophoca cinerea*)) im Mittelpunkt (siehe Abbildungen 4a & b). Die Schüler erhielten verschiedene Beobachtungsaufträge, wobei die Ergebnisse in ihrem Arbeitsheft festgehalten wurden.

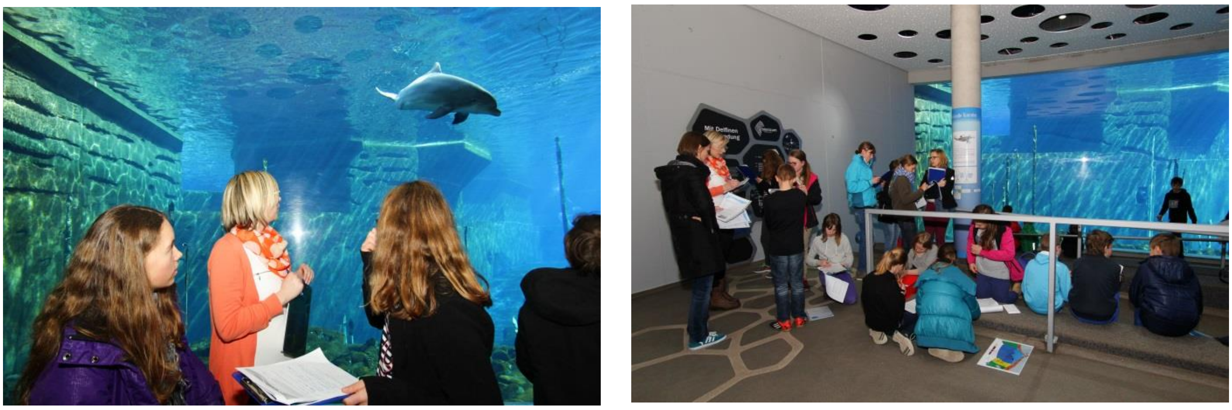

Abbildung 4a & b: Lernen im Aquarium-Modul (Landesamt für Umwelt, 2015)

Bei der Station *Der Strom im Delphinarium* wurden die Tiere in den Aquarien in Bezug auf ihre Schwimmgeschwindigkeiten und ihr Verhalten beobachtet, wobei vor allem die Stromlinienform und die Ernährungsweise der Tiere im Vordergrund standen. Zusätzliche Informationen im Delphinarium halfen den Schülern die Bionik dahinter zu verstehen. Die Station *Das Geheimnis der Delphinschnauze* beschäftigte sich mit der Form der Schnauze der Delphine. Die Schüler sollten eine Zeichnung eines Delphinkopfes anfertigen, bei der das Originalobjekt im Aquarium als Vorbild diente. Diese Zeichnung sollten sie anschließend mit einem Bild eines Tankers vergleichen, um so Analogien feststellen zu können. Die Station *Flosse ist nicht gleich Flosse* beschäftigte sich mit verschiedenen Flossentypen der im Aquarium lebenden Tiere. Dabei wurde auf die homologe Entwicklung der Säugerextremitäten des Delphins und der menschlichen Hand Wert gelegt. Die letzte Station *Kommunikation unter Wasser* beschäftigte sich mit der Kommunikation der Delphine. Die Schüler konnten diese vereinfacht an einer Hörstation direkt im Aquarium kennenlernen. Hierbei wurde zusätzlich das bionische Beispiel des Tsunami-Frühwarnsystems nähergebracht.

3.4.3 Abschlussphase

Die abschließende Phase *Irrgarten Bionicum* wurde in der Ausstellung *Ideenreich Natur* des *Bionicums* im Tiergartens Nürnberg durchgeführt. Hier konnten die Schüler das erlernte

Wissen noch einmal wiederholen, vertiefen und auf neue bionische Beispiele übertragen. Hierbei wurde die Ausstellung mit ihren Experimenten, Computeranimationen, Filmen und auch ein Roboter eingebunden.

3.5 Datenerhebung und Auswertung der Teilarbeiten A-D

Die Genehmigung der Datenerhebung an den Schulen wurde am 03.02.2015 durch das Bayerisches Staatsministerium für Bildung, Kultus, Wissenschaft und Kunst (Zeichen: X.7-BO4106/453/9) erteilt. Die Intervention lief von Februar 2015 bis Juli 2015 im Tiergarten in Nürnberg. Alle Daten wurden schriftlich mit Fragebögen *(„paper-and-pencil-Tests“)* erhoben. Um die Fragebögen exakt zuordnen zu können und die Anonymität zu gewährleisten, wurden diese mit einem Code aus Geschlecht, Geburtsmonat, Jahr und die Anfangsbuchstaben der Mutter sowie deren Hausnummer versehen. Die Anzahl der Schüler variiert aufgrund der unterschiedlichen Anzahl der ausgefüllten Tests. Die Schüler wurden unvorbereitet fünfmal (T0=zwei Wochen vorher, T1=direkt danach, T2=sechs Wochen danach, T3=zwölf Wochen danach, T4=ein Jahr danach) mit unterschiedlichen Instrumenten getestet und im Testungszeitraum nicht von ihren Lehrern zum vorliegenden Inhalt unterrichtet (siehe Abbildung 5).

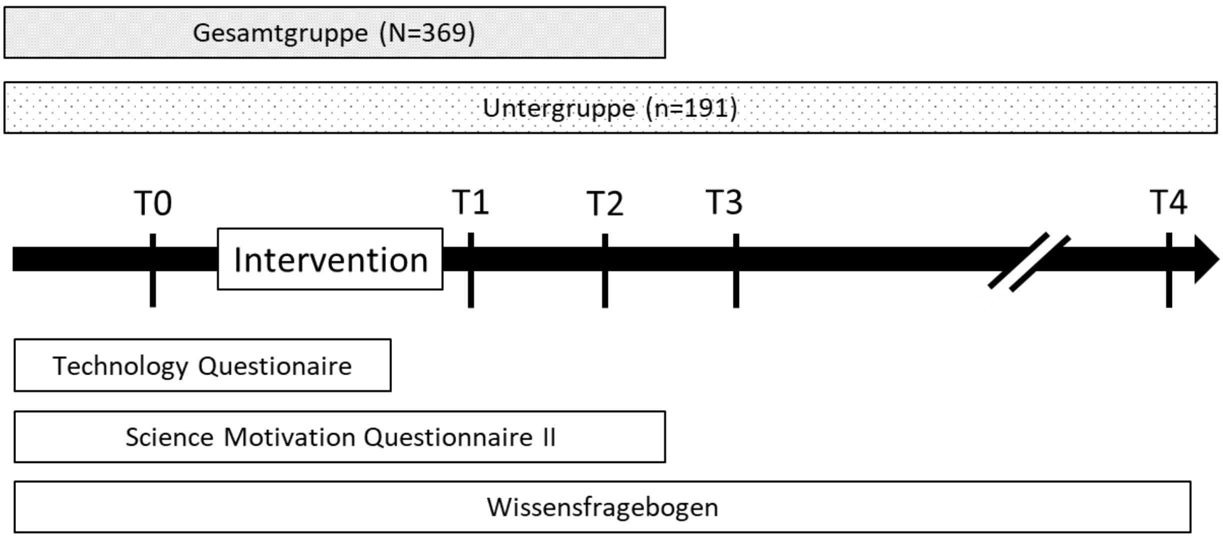

Abbildung 5: Übersicht der verwendeten Instrumente bei den Schülern

Die Studenten und Lehrer wurden jeweils einmal mittels Technology Questionnaire befragt. Die Teilnahme an der Studie war für die Schüler, Studenten und Lehrer freiwillig. Für die statistischen Auswertungen wurde SPSS (Version 22.0 & 23.0) verwendet.

Teilstudie A beschäftigt sich mit Einstellungen zu Technik in verschiedenen Altersgruppen. Alle Altersgruppen füllten den verkürzten Technology Questionnaire (Part B) jeweils einmal aus (Harding & Rennie, 1992). Dieser Fragebogen beschäftigt sich mit der Frage „Was denkst du über Technik?" und beinhaltet zehn items, die in zwei Unterkategorien aufgeteilt sind: zum einen die Unterkategorie Interesse für Technik und zum anderen soziale Aspekte von Technik. Die Schüler werden zum Beispiel gefragt, ob sie sich für Technik interessieren oder ob sie gerne mehr über Technik lernen würden. Bei den sozialen Aspekten geht es unter anderem darum, dass Technik im alltäglichen Leben allgegenwärtig ist, und ob Technik zum Beispiel mehr Gutes als Schlechtes hervorgebracht hat oder auch ob es nützlich ist, Geld für neue Techniken auszugeben (siehe Anhang 5.1). Die Beantwortung der Fragen erfolgte mit Hilfe einer 5-Punkt Likert-Skala.

Es wurden Daten von Schülern, Studenten und Lehrern erhoben (*N*=610): Alle Schüler (*n*=369) besuchten Jahrgangsstufe sechs bayerischer Gymnasien und Realschulen (Alter: *M*=12,14; *SD*=0,57; 47,43% weiblich), die Studenten (*n*=125) waren Studienanfänger biologischer und nicht biologischer Fächer der Universität Bayreuth (Alter: *M* = 22,53, *SD* = 2,82; 76,00% weiblich) und die Lehrer (*n*=116) verschiedener Schulen und unterschiedlicher Fächer wurden in Rahmen einer Fortbildung an der Universität Bayreuth befragt (Alter: *M* = 42,47; *SD*= 10,9; 60,34% weiblich).

Zur Bestätigung der Skala des Technology Questionnaires wurden die Datensätze Faktorenanalysen (Hauptachsenanalyse, Varimax-Rotation) unterzogen. Für alle anschließenden Untersuchungsmethoden wurde der zentrale Grenzwertsatz der Normalverteilung von Daten herangezogen (Field, 2013). Da eine Normalverteilung vorausgesetzt wurde, wurden parametrische Testmethoden durchgeführt, um die Unterschiede in den einzelnen Gruppen vergleichen zu können. Für den Vergleich der Altersgruppen wurde jeweils eine Varianzanalyse (ANOVA) mit anschließenden post-hoc Tests mit Bonferroni-Korrektur für die Sub-Skala Interesse und eine für die Sub-Skala soziale Aspekte durchgeführt. Im Anschluss daran wurden zusätzlich t-Tests durchgeführt, um die Geschlechterunterschiede in den jeweiligen Gruppen zu testen.

In **Teilstudie B** wurde die Intervention entworfen, an der insgesamt 369 Schüler aus 15 verschiedenen sechsten Klassen bayrischer Gymnasien und Realschulen teilnahmen (Alter: *M*=12,14; *SD*=0,57; 47,43% weiblich). Teilstudie B ist der Grundstein für Teilstudie C und D, weswegen diese Schüler ebenfalls für die Teilstudien C und D befragt wurden. Aufgrund der unterschiedlichen Fragenstellungen variierten die Teilnehmer der einzelnen Teilstudien innerhalb der Gesamtstudie jedoch.

Teilstudie C beschäftigt sich mit dem erzeugten Wissenszuwachs, welcher im Interventionsmodul Bionik von Teilstudie B erworben wurde. Das erworbene Wissen wurde unterschieden in Wissen, welches im Sub-Modul Aquarium und im Sub-Modul Seminarraum akquiriert wurde. Insgesamt nahmen 324 Schüler an der Teilstudie mit einem Altersdurchschnitt von *M* =12,2 Jahren teil, wobei 189 Mädchen und 135 Jungen waren.

Zur Überprüfung des jeweiligen Wissensstandes wurde ein selbstentwickelter Multiple-Choice Wissensfragebogen eingesetzt, der jeweils vier Antwortmöglichkeiten bereithielt, wovon jedoch nur eine richtig war (siehe Anhang 5.2). Der Test beinhaltet insgesamt 30 Wissensitems und wurde in drei verschiedene Kategorien aufgeteilt: Seminarraum-Modul, Aquarium-Modul und ein Kombinations-Modul, welches Fragen aus dem gesamten Interventionsmodul Bionik enthielt. Der erste Testzeitpunkt war zwei Wochen vor der Intervention (T0), der zweite direkt nach der Intervention im Tiergarten (T1) und der dritte Testzeitpunkt sechs Wochen danach (T2). Eine Untergruppe von 191 Schülern füllte zusätzlich noch einen vierten Testzeitpunkt zwölf Wochen danach (T3) und einen Fragebogen ein Jahr (T4) nach der Intervention aus (siehe Abbildung 5). Um zu überprüfen, ob eine Verbindung zwischen Vorwissen und Technikbegeisterung der Schüler besteht, wurde Bezug zum Technology Questionnaire genommen.

Des Weiteren wurden zusätzlich 47 Schüler (Alter: *M* =12,3; *SD*=0,61; 57,45% weiblich) im Rahmen der Studie als Test-Retest-Gruppe zweimal befragt und nahmen nicht an der Interventionsstudie teil. Die Test-Retest-Gruppe erhielt die Fragebögen jeweils nur zu Testzeitpunkt T0 und T1.

Um den Wissensfragebogen in unterschiedliche Kategorien einteilen zu können, wurde eine Schwierigkeitsanalyse durchgeführt. Für die Untersuchung der Schwierigkeitsindizes wurde eine Analyse mit den Summenwerten der Teilnehmer durchgeführt, hierbei die Zahl der richtigen Antworten addiert und anschließend durch die Gesamtanzahl der Teilnehmer dividiert. Die Analyse der verschiedenen Testzeitpunkte erfolgte ebenso wie die Geschlechteranalyse mit der parametrischen Testvariante ANOVA und sich anschließender Bonferroni-Korrektur. Die Pearson-Korrelation wurde für den Zusammenhang zwischen Wissen und Technikinteresse durchgeführt. Die Analyse der Test-Retest-Gruppe erfolgte mittels t-Test.

Teilstudie D beschäftigte sich mit der naturwissenschaftlichen Motivation von Schülern in Verbindung mit Technikinteresse. 324 Schüler wurden zu ihrer naturwissenschaftlichen

Motivation dreimal mit Hilfe des Science Motivation Questionnaires II befragt: zwei Wochen vor der Intervention (T0), direkt danach (T1) und sechs Wochen danach (T2) (Glynn et al., 2011). Da die Schüler, die an dieser Studie teilnahmen, jünger waren als die in der Ursprungsstudie, wurden lediglich drei der fünf Sub-Skalen ausgewählt (Intrinsische Motivation, Selbstwirksamkeit, Noten-Motivation) (siehe Anhang 5.3). Zusätzlich wurde zu Testzeitpunkt T0 der verkürzte Technology Questionnaire mit der naturwissenschaftlichen Motivation korreliert, um die Verbindung von Technik und Naturwissenschaften zu überprüfen.

Um die Struktur der Faktorenanalyse der drei Sub-Skalen zu überprüfen, wurde eine Faktorenanalyse (Hauptachsenanalyse) mit Oblimin und Varimax Rotation durchgeführt. Der KMO-Test (Kaiser-Meyer-Olkin- Test) erlaubte eine anschließende Faktorenanalyse. Für die Analyse der unterschiedlichen Testzeitpunkte wurden für die einzelnen Sub-Skalen (neue Sub-Skala: Selbstvertrauen und Noten-Motivation) Varianzanalysen (ANOVA) mit post-hoc Tests und Bonferroni-Korrektur durchgeführt. Dieses parametrische Testverfahren wurde ebenfalls durchgeführt, um die Geschlechterunterschiede zu untersuchen. Auch für die Test-Retest-Gruppe wurde eine Varianzanalyse (ANOVA) für jede Sub-Skala durchgeführt. Die Verbindung von naturwissenschaftlicher Motivation mit Technik wurde mittels Pearson Korrelation untersucht (Selbstvertrauen/Noten-Motivation und Technikinteresse/soziale Aspekte von Technik).

3.6 Ergebnisse und Diskussion

Der Fokus der Gesamtstudie beschäftigt sich mit der Einbettung von Technik und der Verbindung von Technik mit dem kognitiven Wissenserwerb und der naturwissenschaftlichen Motivation. Die Vorstudie bei den verschiedenen Altersgruppen diente zur Analysierung des Istzustandes (Teilstudie A). Aufgrund dessen wurde der Lernzirkel Bionik entworfen (Teilstudie B), ausgeführt und anschließend evaluiert (Teilstudie C & D). Besonderes Augenmerk bei der Evaluierung lag auf der Effektivität der Intervention. Im Zuge dessen wurde die Wissensänderung in den Mittelpunkt gestellt. Zusätzlich wurde die Verbindung von Technik und genereller Motivation, Naturwissenschaften zu erlernen, evaluiert.

Teilstudie A

In Teilstudie A geht es um das Technikinteresse und die sozialen Aspekten von Technik in verschiedenen Altersgruppen. Da der Technology Questionnaire schon zwanzig Jahre alt ist, wurde zuerst die Anwendbarkeit dieses Instruments auf verschiedene Altersgruppen überprüft und Faktorenanalysen durchgeführt. Die Kaiser-Meyer-Olkin-Tests (KMO) haben dafür angemessene Ergebnisse gezeigt (0,74-0,82) (Kaiser, 1970). Auch die Reliabilität der einzelnen Sub-Skalen haben mit 0,62 bis 0,83 gute Ergebnisse erzielt (Kline, 1993). Die explorative Faktorenanalyse lieferte für alle drei Altersgruppen vergleichbare Ergebnisse, indem eine Zwei-Faktoren Lösung generiert wurde. Es ergaben sich lediglich kleine Abweichungen einer Kreuzladung (I2) bei den Schülern und einer Ladung unter 0,3 in der Lehrergruppe. In allen anderen Fällen konnte die Faktorenlösung der Originalarbeit bestätigt werden.

Das Interesse hat seinen Höchststand bei der Altersklasse der Schüler und fällt dann hin zu den Studenten und Lehrern, wobei sich die Studenten- und Lehrergruppe nicht signifikant voneinander unterscheiden. Dies steht im Einklang mit der Literatur, in der vor allem die Förderung des Interesses in jungen Jahren im Vordergrund steht, da in dieser Zeit Präferenzen und Meiningen etabliert werden (Lips, 2004).

Die sozialen Aspekte von Technik hingegen zeigen einen gegenläufigen Trend, die niedrigsten sozialen Werte zeigen die Schüler, wobei diese bei den Studenten und Lehrern ansteigen. Positive soziale Einstellungen wachsen also über die Altersgruppen hinweg, was auch die Literatur bestätigt. Bouras & Albe (2008) haben die Abhängigkeit der Gesellschaft von der Technik als Grund hierfür angegeben.

Auch die Betrachtung der Geschlechterunterschiede war ein Hauptaugenmerk in dieser Studie. Diese signifikanten Unterschiede fanden sich in jeder Altersgruppe, sowohl in der Sub-Skala Interesse als auch in der Sub-Skala soziale Aspekte, wobei jeweils das männliche Geschlecht mehr Interesse und auch mehr soziale Aspekte zeigte. Lediglich die Lehrergruppe zeigte bei den sozialen Aspekten von Technik keine Geschlechterunterschiede.

Schon in der frühen Kindheit werden erste Präferenzen sichtbar, indem die Kinder die stereotypischen Bilder der Geschlechter kennenlernen (Dasgupta & Stout, 2014). Die Pubertät ist ein einschneidendes Erlebnis in der Entwicklung eines jungen Menschen, genau in dieser Zeit formen sich viele Interessen und Einstellungen (Baram-Tsabari & Yarden, 2011). Auch die Freunde spielen eine entscheidende Rolle bei der Ausbildung von naturwissenschaftlichen Präferenzen, indem sie sich gegenseitig in ihren Interessen beeinflussen und oftmals dieselben Kurse belegen (Riegle-Crumb et al., 2006). Aber auch im Erwachsenenalter sind Frauen in den Naturwissenschaften und der Technik häufig unterrepräsentiert und fühlen sich in männerdominierten Gebieten nicht wohl (Murphy, Steele, & Gross, 2007). In den sozialen

Aspekten ist das Geschlechterverhältnis oft ausgeglichen, was wohl auf die soziale Motivation der Frauen zurückzuführen ist (Lips, 2004).

Teilstudie B

Bionik ist ein neues und innovatives Forschungsfeld, welches Biologie, Technologie und andere Naturwissenschaften vereint, um technische Probleme zu lösen, wobei die Natur als Vorbild dient (Nachtigall & Wisser, 2013). Es etablieren sich immer mehr bionische Erfindungen im Alltag, aus diesem Grund wurde in Teilstudie B der Lernzirkel Bionik entworfen. Das Ergebnis von Teilstudie B ist das in 3.4 vorgestellte Interventionsmodul Bionik. Der Lernzirkel arbeitet mit kooperativen Lernformen, Hands-on Stationen und ist im außerschulischen Lernort Zoo und der Ausstellung *Ideenreich Natur* angesiedelt. Die Intervention Bionik gilt als Grundlage für Teilstudie C und Teilstudie D.

Teilstudie C

Teilstudie C beschäftigte sich mit dem Erwerb von kurzzeitigem, mittelfristigem und langfristigem Wissen, welcher durch die Teilnahme am Unterrichtsmodul Bionik generiert wurde. Zusätzlich wurde die Verbindung von Vorwissen und Technik evaluiert. Die Wissensänderung ist sowohl im gesamten Modul als auch in allen Sub-Modulen (Aquarium-Modul, Seminarraum-Modul, Kombination-Modul) vorhanden. Die niedrigsten Werte zeigte das Vorwissenslevel, gefolgt von einem Anstieg direkt nach der Intervention und einem erneuten Abfall sechs Wochen nach der Intervention, wobei die Werte des Wissenslevels immer noch höher lagen als das Ausgangslevel.

Auch die Langzeitstudie zeigte mit einer Untergruppe der Schüler äquivalente Ergebnisse bei fünf Testzeitpunkten. Langfristiges Wissen war auch nach einer Zeitspanne von einem Jahr noch existent. Hier wurde auch der niedrigste Wert für den Vorwissensstand gezeigt, gefolgt von einem Anstieg direkt nach der Intervention und einem Abfall sechs Wochen danach. Die folgenden Wissenswerte nach zwölf Wochen und einem Jahr zeigten jeweils dasselbe Level wie das nach sechs Wochen.

Diese Ergebnisse bestätigen die Studie von Randler, Baumgärtner, Eisele, & Kienzle (2007), denn auch sie wiesen Langzeiteffekt des Wissens in einem zoologischen Kontext nach. Die meisten Studien mit Vor- und Nachtest-Design testen das Wissen jedoch nur noch ein- oder zweimal in sehr kurzen Abständen (Goldschmidt & Bogner, 2015; Langheinrich & Bogner, 2016; Gerstner & Bogner, 2010). Langzeitstudien mit drei oder mehr Nachtests, die sich über ein Jahr erstrecken wie in der vorliegenden Studie, sind in der Literatur sehr rar, da sich der organisatorische Aufwand in der Schule als sehr schwierig erweist. Dennoch konnten zum Beispiel Fančovičová & Prokop (2011), Schmid & Bogner (2015), Randler et al. (2007) als auch die vorliegende Studie solche Langzeiteffekte in Bezug auf Wissen zeigen.

Die Korrelation des Technology Questionnaires (Interesse und soziale Aspekte) mit dem Vorwissen zeigte signifikante Effekte für alle Sub-Module. In unserer Intervention sollte Bionik die Verbindung zwischen Technik, Naturwissenschaften und dem Wissen herstellen, wobei Technikpräferenzen hohe Werte im Vorwissen zeigten. Diejenigen Schüler, die Technik interessiert sind und auch die sozialen Aspekte der Technik aufweisen, haben ein höheres Vorwissen als die nicht technikbegeisterten Schüler. Wenn die Lehrer diese Vorbedingungen erkennen, können Unterrichtsmethoden angepasst und verbessert werden, was durch Lovelace & Brickman (2013) bestätigt wurde. Auch das Vorwissen der Lehrer selbst spielt dabei eine entscheidende Rolle, wie Rohaan, Taconis, & Jochems (2010) gezeigt haben. Initiativen mit technikbasiertem Fokus, wie unsere Bionik-Intervention, können Schüler möglicherweise überzeugen Naturwissenschaften und Technik interessant zu finden. Ein Ansatz könnte auch die Begegnung mit richtigen Forschern sein, um die „echte" Technologie ins Klassenzimmer zu bringen (Stein, Ginns, & McDonald, 2006).

Teilstudie D

In Teilstudie D wurde die naturwissenschaftliche Motivation der Schüler durch den Science Motivation Questionnaire II erfasst. Die Überprüfung des Fragebogens auf die Anwendbarkeit für die zu evaluierende Altersstufe erfolgte durch eine Faktorenanalyse. Der KMO-Tests erlaubte mit 0,923 eine gute Durchführbarkeit dieses Testverfahrens (Kaiser, 1970). Die Reliabilität der einzelnen Sub-Skalen reichten von ,80 bis ,90 (Kline, 1993). Die explorative Faktorenanalyse mit Varimax Rotation lieferte eine gänzlich andere Faktorenlösung als in der Originalarbeit. Die ursprünglichen drei Faktoren Selbstwirksamkeit (SE), intrinsische Motivation (IM) und Noten-Motivation (GM) wurden auf zwei Faktoren reduziert. Die Faktoren intrinsische Motivation und Selbstwirksamkeit wurden in einem neuen Faktor Selbstvertrauen (SC) vereint, wohingegen die Sub-Skala der Noten-Motivation erhalten blieb.

Ein Grund für die Vereinigung der beiden Teilskalen könnte sein, dass Schüler genau in diesem Alter womöglich nicht zwischen intrinsische Motivation und Selbstwirksamkeit unterschieden können. Ursprünglich wurde diese Skala für Studierende an Universitäten entwickelt und nicht für Schüler, was den größten Unterschied darstellen dürfte (Glynn et al., 2011). Da die Schüler in der vorliegenden Studie aber viel jünger sind, könnte es sein, dass die meisten noch kein Selbstwirksamkeitserleben haben. Zudem haben Zimmerman & Kitsantas (1997) einen engen Zusammenhang zwischen intrinsischer Motivation und Selbstwirksamkeit feststellen können, was die Verknüpfung der beiden Teilgebiete nahelegt.

Um zu sehen, ob die Schüler durch die Bionik-Intervention ihre Motivation gegenüber Naturwissenschaften steigern konnten, wurde diese dreimal überprüft. Direkt nach der Intervention konnte das Selbstvertrauen (SC) für Naturwissenschaften signifikant gesteigert werden. Dieser Anstieg könnte durch mehrere Einflussfaktoren wie kooperative Lernformen, hands-on Stationen, außerschulischer Lernort oder durch die lebenden Tiere bedingt sein, was sich auch in der Literatur wiederfindet (Mayer, 2004; Poudel et al. 2005; Kyndt et al., 2013).

Dieser Anstieg konnte nach sechs Wochen nicht mehr beobachtet werden. Dieses Ergebnis zeigt, dass kurzfristig eine Änderung stattfinden konnte, jedoch nicht langanhaltend. Für ein langanhaltendes Ergebnis müsste man immer wieder Interventionen zur naturwissenschaftlichen Motivation durchführen oder diese im Unterricht weiter fördern. Die Noten-Motivation konnte mittels dieser Studie nicht beeinflusst werden, obwohl viele Studien, wie die von Terry, Mills, & Sollosy (2008), die Benotung als entscheidende Rolle für die Motivation sehen.

Die beiden Sub-Skalen wurden zusätzlich auf Geschlechterunterschiede untersucht. Weder in der Selbstvertrauens- noch in der Noten-Motivation Sub-Skala gab es einen Geschlechterunterschied bezüglich der naturwissenschaftlichen Motivation. Das Fehlen von geschlechterspezifischen Unterschieden konnte mit Literatur bekräftigt werden (Zeyer & Wolf, 2010; Zeyer, 2010). Wigfield (1996) wies darauf hin, dass diese Geschlechterunterschiede erst im Laufe der Sekundarstufe ausgebildet werden und in der Grundschule völlig fehlen. Die Studienteilnehmer in Jahrgangstufe sechs befinden sich genau in diesem Übergang zwischen Primar- und Sekundarstufe.

Die Verbindung von Technik und naturwissenschaftlicher Motivation wurde mittels Korrelation der Sub-Skalen Interesse, soziale Aspekte von Technik, Selbstvertrauen und Noten-Motivation hergestellt. Die Unterskalen Selbstvertrauen und Noten-Motivation korrelieren zu jedem Testzeitpunkt miteinander, was die Verbindung der generellen naturwissenschaftlichen Motivation darstellt, wie auch in der Literatur gezeigt wurde (Glynn et al., 2011).

Die Korrelation vom Technology Questionnaire zur naturwissenschaftlichen Motivation liefert hingegen nur eine kleine Korrelation zwischen Interesse für Technik und

Selbstvertrauen für Naturwissenschaften. Als mögliche Ursache hierfür kann Bionik als Verbindung der verwandten Bereiche von Technik und Naturwissenschaften angeführt werden (Bannasch, 2009), denn diese Bereiche überschneiden sich und gehören zusammen in unserer „naturwissenschaftlichen-Technikgesellschaft“ (Aikenhead & Ryan, 1992).

3.7 Schlussfolgerung und Ausblick

Die Studie beschäftigte sich mit der Verbindung von Naturwissenschaften und Technik, hierbei wurde die Technikbegeisterung von Schülern, Studenten und Lehrern evaluiert. Schüler sind die am meisten begeisterungsfähige Altersgruppe für neue technische Erfindungen. In den sozialen Aspekten der Technik hingegen haben die Lehrer die größte Kompetenz inne. In beiden technikbasierten Konzepten kristallisierte sich ein spezifischer Geschlechterunterschied heraus, welcher die Technikbegeisterung der männlichen Teilnehmer zum Vorschein brachte.

Die Verbindung zwischen Natur und Technik, welche durch das Themengebiet Bionik in einem Lernzirkel realisiert wurde, war ein weiterer zentraler Ausgangspunkt der Studie. Die Kopplung von schülerzentriertem Unterricht zum Themenbereich Bionik mit verschiedenen Modulen am außerschulischen Lernort Zoo erwies sich dafür als sehr effektiv. Die Realisierung des Seminarraum-Moduls ist nicht an den Tiergarten gebunden und könnte theoretisch auch in einem klassischen Klassenzimmer durchgeführt werden. Der Wissenszuwachs konnte über ein Jahr hinweg konstant gehalten werden. Dieser Langzeit-Effekt konnte leider mit der naturwissenschaftlichen Motivation nicht erreicht werden. Diese konnte lediglich kurzfristig nach der Intervention gesteigert werden und fiel nach sechs Wochen wieder auf das Ausgangsniveau.

Um langfristige Erfolge in der Steigerung der Motivation für Naturwissenschaften erzielen zu können, wäre es vonnöten, solche Intervention oder andere Bemühungen öfter in den Schulalltag einzubauen, um die Schüler auch im alltäglichen Unterricht für Naturwissenschaften motivieren zu können. Hierbei ist es vor allem wichtig, dass die Schüler möglichst früh mit Naturwissenschaften in Kontakt kommen und sich zudem aktiv damit beschäftigen, um die Scheu davor bzw. die Scheu vor Paradigmen, welche oftmals an Naturwissenschaften und der Technik haften, gar nicht entstehen zu lassen.

Die stetige Fortentwicklung von Naturwissenschaften und Technik wird auch in Zukunft in derselben Geschwindigkeit voranschreiten wie im letzten Jahrzehnt oder sogar noch an Fahrtwind aufnehmen. Technik wird immer mehr in den Unterricht integriert werden, sei es durch Tablet-PCs, durch interaktive White-boards oder durch neue technikbasierte, naturwissenschaftlich geprägte Phänomene, die unseren Alltag schon heute zum Großteil bestimmen. Der naturwissenschaftliche Unterricht kann durch den Einsatz neuer Technologien Technik integrieren und den Schülern so fächerübergreifendes Wissen und Handeln näher bringen. Deswegen ist es wichtig, die Schüler frühzeitig mit Technik und Naturwissenschaften zu konfrontieren, um ihnen optimale Voraussetzungen für ihr späteres Leben außerhalb der Schule zu schaffen.

Dieses Themengebiet ist ein hervorragendes Beispiel des neuen Lehrplan PLUS, welcher weggeht von reinem Faktenwissen hin zu Kompetenzen und Handlungsfähigkeiten von Schülern. Mit dieser Reform wurde ein großer Schritt in die richtige Richtung für die Entwicklung junger Erwachsenen getan. Diese Intervention ist nur eines von vielen Beispielen, wie man Naturwissenschaften und Technik in die Schule bringen kann, es kann aber ein Anfang sein, um das Interesse und die Motivation dafür zu entfachen.

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5 TEILARBEITEN

5.1 Publikationsliste

Die aus der vorliegenden Arbeit hervorgegangenen Publikationsmanuskripte sind im Folgenden aufgeführt:

(1) Marth, M. & Bogner, F.X. (2017)
Monitoring a gender gap in interest and social implications of technology in different age groups: a revision of the Technology Questionnaire
International Journal of Technology and Design Education
(submitted)

(2) Marth, M. & Bogner, F.X. (2017)
BIONICS- an out-of-school day in the zoo
The American Biology Teacher
(in press)

(3) Marth, M. & Bogner, F.X. (2017)
Does the issue of bionics within a student-centered, zoological garden module generate long-term knowledge?
Studies in Educational Evaluation
(published)

(4) Marth, M. & Bogner, F.X. (2017)
How a hands-on BIONICS lesson may intervene with science motivation and technology interest
International Journal of Learning, Teaching and Educational Research
(published)

5.2 Darstellung des Eigenanteils

Der Technology Questionnaire wurde der Literatur entnommen und gemäß der thematischen Gegebenheiten von mir für Teilstudie A angepasst. Die Durchführung der Befragung, die Auswertung und Interpretation der Daten erfolgte durch mich.

Der Lernzirkel in Teilstudie B wurde von mir entworfen, angefertigt und auch selbst im Tiergarten Nürnberg ausgeführt. Dabei wurden die Ideen zu den Materialien (Modellen, Versuchen, Texte und Experimente) teilweise aus Quellen entnommen, von mir adressatengerecht angepasst oder selbstständig entwickelt.

Auch die Auswertung und Interpretation rund um das Wissen (Teilarbeit C) und die naturwissenschaftliche Motivation (Teilarbeit D) erfolgte durch mich und Herrn Prof. F.X. Bogner. Die eingesetzten Fragebögen dazu wurden entweder von mir selbst konzipiert oder der Literatur entnommen.

Alle Teilarbeiten wurden von mir selbstständig als Erstautorin konzipiert, verfasst und mit Hilfe von Herrn Prof. F.X. Bogner überarbeitet.

5.3 Teilarbeit A

International Journal of Technology and Design Education. Under Submission.
Manuskript Nummer: ITDE-D-17-00154
Juli 2017

Monitoring a gender gap in interest and social implications of technology in different age groups: a revision of the Technology Questionnaire.

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Monitoring a gender gap in interest and social implications of technology in different age groups: a revision of the Technology Questionnaire

Abstract

Technology determines our everyday life although many of us still have neither special knowledge nor interest. The introduction to technology fields starts at a young age, where interest in technology itself develops as well as social aspects of technology. Our study focused on a reliable and valid empirical monitoring of interest in and social implications of technology in three different age-groups. Consequently, we applied an existing scale (adjusted for adults) to 610 participants and examined the factor structure for the single groups. We confirmed factor structure separately for school students while this was true for the very same age group (N=369) as applied in the original scale. Nevertheless, the scale also revealed the same structure to other age-groups such as university freshmen (N= 125) and in-service teacher (=116). Interestingly a gender gap occurs in all age groups for each factor. Each of the two factors build a single sub-scale: namely interest in technology and social aspects of technology: Not surprisingly, male participants showed significantly higher interest and social adjustment to technology. Only in the social context for male and female in-service teacher group occurs no gender difference.

Keywords: interest in technology, social implications of technology, university freshman, gender gap, technology in school, STEM

Introduction

There are many definitions of technology in the literature. Mc Robbie (2000) summarized the different views by pointing to the main dimensions of technology: a human dimension, a social dimension, technology as a process, a situated dimension and an artifacts dimension. In our case, the social dimension of technology and general interest in technology are of interest. Most people regard technology as boring, hard to learn and also often associated with risks (Ardies, De Maeyer, & David Gijbels, 2013). When beginning science education, students have to feel positive, confident and make favorable adventures and experiences towards science so that they later are more successful in their scientific career in school and university (Akpınar, Yıldız, Tatar, & Ergin, 2009) Therefore, building positive attitudes towards science and technology is of great importance (Akpınar et al., 2009). Negative experiences in science lessons may manifest attitudes towards science in a negative way, which later-on is difficult to change and may remain for the rest of students' lives (Simpson & Oliver, 1990). Thus, general attitudes towards science are decreasing over the school life although students' thoughts about utility of science increase correspondingly (George, 2006). Students regard science as very useful and important although negative attitudes towards science prevent them from choosing science courses (George, 2006).

Technology education is more important than ever but public views are still negative (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). In agreement with Ardies et al. (2013) who described interest in technology during the school career of students in the Flemish context. Ardies et al. (2015) showed that interest in technology decreased from the first to the second level of secondary education, especially for girls. Time devoted to teaching correlates in this study positively with interest in technology. Parents also influence students as parents with technology occupations for example have positive influence on attitudes and interest in technology (Ardies et al., 2015). Finally technological toys at home show positive influences on those variables considerably (Ardies et al., 2015).

Talking about famous scientists often leads to names such as Einstein, Newton, Bohr or Pasteur (Otto, 1991). These personalities produce the typical perception of science and technology as a "male-dominated profession" (National science foundation, 1988). Famous women like Curie, Hodgkin or Herschel are rarely mentioned (Otto, 1991). These differences are already seen in the STEM (Science, Technology, Engineering and Math) sector: Women are in the minority in both STEM jobs and STEM degrees (Beede, Julian, & Langdon, 2011). In these disciplines, males achieve better test results and proceed to better careers (Miyake et al., 2010). This gender difference occurs in all age-groups and is perhaps already based at school age, where girls have more negative attitudes towards science (Weinburgh, 1995 & Cannon & Simpson, 1985). Males often show more positive attitudes for enjoyment, motivation and self-concept of science, females on the other hand had more positive attitudes in valuing society, and prefer to please teachers, parents and society (Weinburgh, 2000).

Wolters (1989) described technology education as a chance to form attitudes towards technology, and to bridge gender gaps in young age. For that it is necessary to train pre-service teachers in technology skills to generate positive attitudes towards technology and a global conception of technology (Wolters, 1989). In particular, primary school teachers seem to have nearly no perception of technology or technology education, which points to the need to provide more information about technology to pre-service teacher to improve the general aspects of technology (Mc Robbie, 2000). Furthermore, many secondary school teachers associate technology with subject specialization rather than as an extra science subject. When they have asked what students should learn, they favored technology in their own subject area as well as regarding education in technology as an implementation of science in general (Alister & Carr, 1992). With this knowledge in mind, education of pre-service teacher's as well as in-service teacher professional development efforts for technology may produce benefits. Students should be taught that technology is everywhere and supports their everyday life (Wolters, 1989). If there is no separate technology subject in schools, Wolters (1989) suggested introducing technology into established curricula. Such an approach was introduced into the Bavarian curriculum more than a decade ago (ISB, 2004), as policy makers aimed to bring more technology into school. They proposed a new Subject called "Nature and Technology". Nevertheless, up to now no study exists to monitor the effects in a school context of more technology in school and the effectiveness of such a subject in school context.

Development of the Questionnaire

Studies evaluating interest in technology in Germany are rare, especially regarding gender differences. For the measurement of technology interest, a short instrument is needed. To measure these pre-perceptions of interest in technology and the social aspects or implications of technology we use the Part B of the Technology Questionnaire (Harding & Rennie, 1992). Questionnaires in the technology context have a long history: In the 1980's a first questionnaire was the Dutch PATT, that monitored pupil's attitudes towards technology. The PATT Questionnaire consisted of 10 scales with too many items measuring the attitudes and cognitive components of technology (Wolters, 1989). That scale has repeatedly been confirmed reliable and valid. The follow-up Questionnaire, the APAT (Attitudes and Perceptions About Technology) instrument reduced the number of sub-scales to seven: interest, career in technology, technology is easy, importance of Technology, technology as a design process, diversity of technology and technology as problem solving (Rennie & Treagust, 1989). A further follow-up study educed the item number further covering four sub-scales: diversity, design, interest and social aspects. The best five items of each sub-scale were first published by Harding & Rennie (1992) in their Technology Questionnaire. In our present study, we applied this Technology Questionnaire (TQ) to answer four questions:

Research Questions:

1. Is the Technology Questionnaire suitable for a German language context?
2. Is a two-factorial solution of the shortened TQ (sTQ) suitable to samples of different age groups?
3. Are there differences between different age sub-samples?
4. Are there gender differences?

Procedures and methods

Subjects were 610 participants of different age groups divided into three sub-samples (i) 6th graders (lower secondary education), (ii) university students from different faculties and (iii) in-service science teachers (see table1).

Table 1: Summary values of the sub-samples participating in the main studies

	N	Age		Gender [%]	
		M	*SD*	female	male
school students	369	12.14	0.573	47.43	52.57
university freshmen	125	22.53	2.828	76	24
in-service teachers	116	42.47	10.914	60.34	39.66

Scale

We applied the short Version of the Technology Questionnaire (shortened TQ=sTQ) (Harding & Rennie, 1992) using Part B: “What do you think about technology?” with the sub-scales "interest in technology" and “social aspects or implications of technology”. Participants were requested to complete the 10 item questionnaire: “interest in technology” (5items) and “social aspects or implications of technology” (5 items). In order to hide the structure all items were collated. All items followed a five point Likert scale system (1 = strongly disagree, 2 = disagree, 3 = can`t decide, 4 = agree, 5 = strongly agree).

Statistics

For statistical analyses, SPSS (Version 22.0) was used. First we repeated the factor analysis of Rennie & Jarvis (1995a) by using the principal axis factoring method and a varimax rotated solution. The factor analysis was completed for each age group separately in this study. Items with cross-loadings and factor loadings below .3 were removed (Stevens 2009, Nunnally & Bernstein 1994).

The central limit theorem supports accepting a normal distribution if the sample size exceeds 30 (Field, 2013). We decided to measure the results using parametric statistical methods. To measure the significance of differences between the groups, we used univariate ANOVA with Bonferonni post hoc tests. We used mean scores subsequently splitting the age groups by gender. T-Tests were used to analyze gender differences within groups.

Results

The Kaiser-Meyer-Olkin (KMO) test showed a reasonable sample suitability with scores ranging between .74 and .82. (Kaiser, 1970). Kaiser (1974) regarded scores exceeding .8 as sufficient. We used the KMO test separately for the different age groups (see table 1). Only the KMO of the university freshmen scored below .8. The total explained variance of the factor solution was acceptable (Lienert & Raatz, 1998). Cronbach`s alpha of the whole scale (interest & social aspect) and the different sub-scales: interest (I) and social aspects (S) showed good overall reliability (Kline, 1993) (see table 2).

Table 2: The Technology Questionnaire: KMO-test, total variance and Reliabilities of the whole scale and the sub-scales

	Students	University freshman	Teacher
KMO	.82	.74	.80
Total variance %	35.66	42.30	40.72
Reliability I & S	.77	.78	.81
Reliability I	.78	.83	.81
Reliability S	.67	.62	.71

The explorative factor analysis extracted two factors for every single age group as suggested by Rennie & Jarvis (1995a). The re-checking of the factor analysis in different age groups was concordant. All three age-groups produced the same structure of the two factors although some differences appeared: One cross-loading in the teachers sample solution was below .3 (item I2) and the item subsequently dropped. The factor loading of the two factors were high (see table 3). Consequently, part B of the TQ Questionnaire showed the same structure for different groups.

Table 3: The Technology Questionnaire: loadings and cross loadings of items

		Original Scale		Students Scale		University freshmen Scale		Teacher Scale	
		Factor loadings							
	Item	1	2	1	2	1	2	1	2
I1	I am interested in technology.	0.69		0.83		0.95		0.80	
I2	I would like to learn more about technology.	0.75		0.72	0.46	0.90		0.69	
I3	I would like a career in technology later on.	0.74		0.68		0.64		0.57	
I4	I like to read books and magazines about technology.	0.76		0.72		0.67		0.88	
I5	I would like to join a hobby club about technology.	0.73		0.85		0.33		0.47	
S1	Technology makes the world a better place to live in.		0.73		0.68		0.35		0.42
S2	Technology has brought more good things than bad things.		0.68		0.39		0.46		0.72
S3	It is worth spending money on technology.		0.57		0.58		0.35		-
S4	Inventions in technology are doing more good than harm.		0.60		0.47		0.42		0.73
S5	Technology is needed by everybody.		0.67		0.47		0.30		0.32

Implementation of the Technology Questionnaire in different age-groups

The variance homogeneity test shows that the data are not optimal for analysis with ANOVA ($p=.119$ (social aspects); $p=.031$ (interest). The level of significance needs to be improved from $p=.05$ to $p=.01$ (Zöfel, 2001). A univariate ANOVA showed differences for the 3 age groups the two separated sections “interest” and “social aspects”, for “interest” $F(2, 598)=23{,}406$, $p <.001$, $\omega= .263$ and for “social aspects” $F(2, 606)=18{,}602$, $p <.001$, $\omega= .228$(see Figure 1). The Bonferroni post-hoc tests showed significant differences between the different age groups in the different parts of the TQ. In “interest” there is a significant difference between students ($M=2.85$, $SE=.046$) and university freshman ($M=2.26$, $SE=.069$) ($p <.001$) as well as a significant difference between students and science teachers ($M=2.58$, $SE=.072$) ($p=.008$). The “interest” mean scores of the university freshman and the science teachers were not significantly different ($p=.014$). The second part of the TQ “social aspects” produced similar results. There is a significant difference between students (M=3.20, SE=.034) and university freshmen (M=3.46, SE=.045) (p <.001) as well as between student and science teacher (M=3.54, SE=.025) (p <.001). Here too is no significant difference between university freshman and science teachers (p=.943).

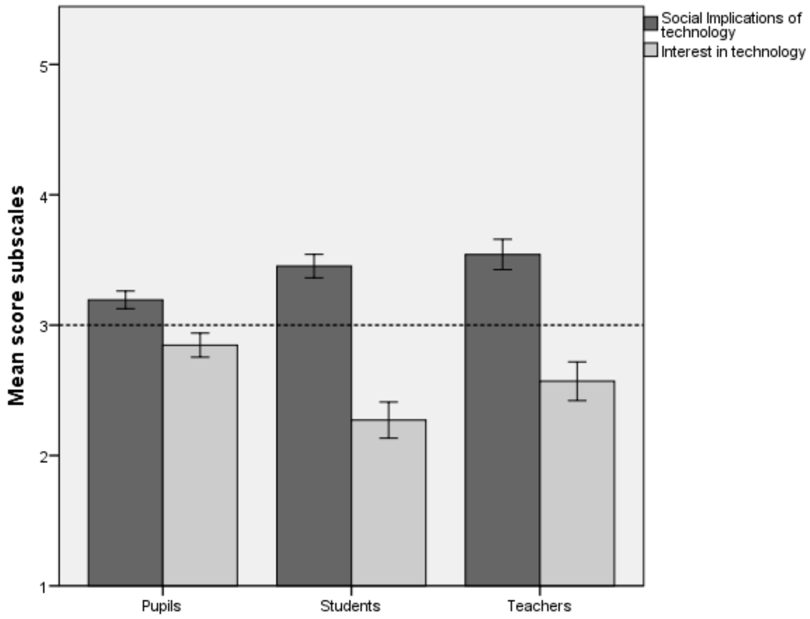

Figure 1: Interest in technology and social implications in technology split by different group; Bars are 95% intervals

Further analysis compared the age-groups with respect to gender and sub-scale as shown in figure 2a and 2b.

Interest

The interest sub-scale showed a gender difference in the various age groups (see figure 2b). The distinction -.75, 95% CI [-.91, -.58] between the female students (M=2.46, SE=.06) and the male students (M=3.20, SE=.06) was significant (t (366) = -8.92, p <.001, d=.424) Additionally the difference -0.79, 95% CI [-1.10, -.48] between the female university freshman (M=2.08, SE=0.07) and the male university freshman (M=2.87, SE=.14) was also significant (t (123) = -5.20, p <.001, d=.614). The teacher sample also show a significant (t (105) = -4.38, p <.001, d=.408) gender gap -.61, 95% CI [-.89, -.33] as female teachers (M=2.30, SE=.10) scored lower than males (M=2.91, SE=.10). The gender gap appears in all age groups in the sub-scale interest.

Social

Social aspects and impact also showed a gender difference (see figure 2a). The disparity -.26, 95% CI [-.39, -.13] between the female students (M=3.06, SE=.044) and the male students

(M=3.32, SE=.04) was significant (t (368) = -4.00, p <.001, d=.205).As well the difference -.45, 95% CI [-.66, -.23] between the female university freshman (M=3.35, SE=0.05) and the male university freshman (M=3.80, SE=.09) was significant (t (123) = -4.23, p <.001, d=.541). The difference -.09, 95% CI [-.32, -.13] between the female teachers (M=3.49, SE=.07) and the male teachers (M=3.58, SE=.09) was not significant (t (113) = -.85, p= .396, d=.087). These differences are significant only in two groups (students, university freshmen). In the teachers group, there is no significant difference between female and male participants.

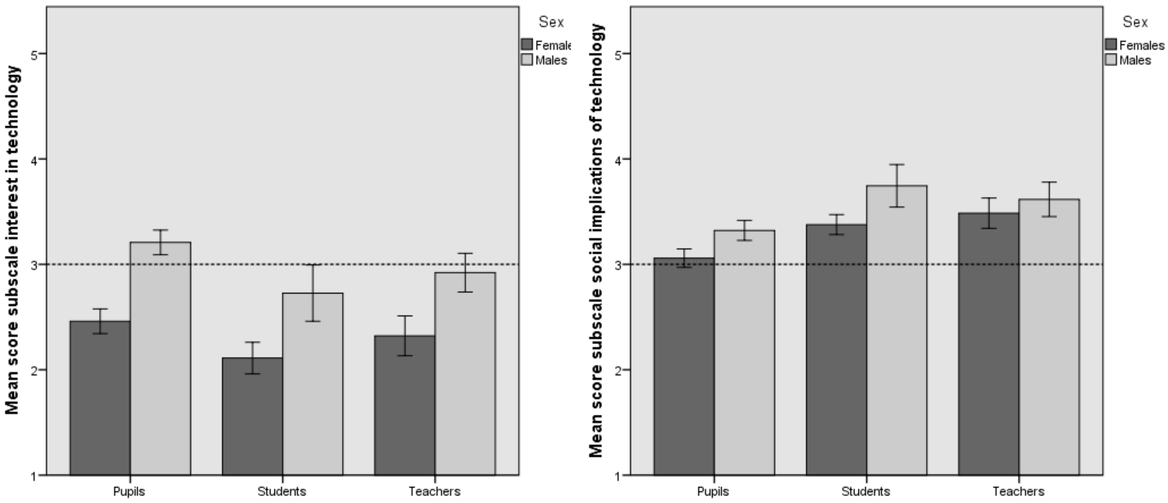

Figure 2a & b: Interest in technology scores (a) and social implications of technology (b) scores split by different group and gender; Bars are 95% intervals

Discussion

Scale application

The instrument of Rennie & Jarvis (1995a), although applied in a short version, is shown as suitable for a German sample, too. Although the scale was developed 20 years ago, both sub-scales showed a similar loading pattern labeled "interest in technology" (I) and "social aspects of technology"(S). This fact is surprising as technology has developed fast and new technology is affecting the lives of students (Subrahmanyam, Greenfield, Kraut, & Gross, 2001), for example, in the use of cell phones, portable computers or smart watches (Rawassizadeh, Price, & Petre, 2014). Additionally, social media are increasingly intervening with our daily life (O’Keeffe & Clarke-Pearson, 2011), which twenty years ago, when the scale was originally developed it was still inconceivable that everybody, especially in the observed age group, would be using technology in this way. Technology is now everywhere and almost nothing works without technology. That was why our sample selection was extended to freshmen and in-service teachers in order to cover potential age-variations, in line with the study of Langheinrich, Schönfelder, & Bogner (2016), where an existing scale (quantifying computer self-concept) was extended to other age groups but showed the same structure, too. Another example of successful application has been demonstrated for the environmental value model published by Munoz, Bogner, Clement, & Carvalho (2009) where a scale originally designed for to adolescents (Bogner & Wiseman 1999 & 2002) was successfully applied to pre- and in-service teachers and showed the same structure.

An ideal numeracy of categories is needed to produce a reliable questionnaire presentation (Matell & Jacoby, 1971). Questionnaires frequently follow a five point Likert-scale response pattern in order to reflect views, including a neutral position permitting participants to declare an undecided position (Garland, 1991). We followed this by allocated the 1 to the lowest score and 5 to the highest one. Although this procedure differed from that of Rennie & Jarvis (1995a) we optimize for this representation the numbers of answering the likert-scale as it allocated low response numbers to indicate low preferences (1=is low preference) and high ones high (5=is high preference) as Bogner & Wiseman (2002) do.

Age groups

The age-group with highest interest scores were the young students, freshmen and in-service teachers scoring significantly lower than students. Interest in technology is apparently high in school and drops later, with scoring lowest level in university time. This is quite in line with earlier studies where interest of technology needs to be promoted in younger school classes, as career preferences are established at young ages (Lips, 2004). The repeatedly reported major problem of dropping interest scores in the subsequent course of school time remains (Speering & Rennie, 1996). For instance, the transition from primary to secondary school is frequently reported a major step in the lives of young people. Primarily for girls, the scientific subject seems to fail to meet expectations, and to determine later career choices (Speering & Rennie, 1996). This anti-technology preference in school seems at least partly to be ascribable to teachers, as primary school teachers often show less preference towards technology (Mc Robbie, 2000). This alone may prevent the introduction of new technology issues into school, as Stein, Ginns, & McDonald (2006) have pointed out many difficulties in teaching technology and thus to improve understanding of technology. However, the sub-scale social aspects of technology show the opposite pattern, as positive preferences increase with age: Freshmen and in-service teachers score substantially higher and show more social implications and social responsibilities than school students do. Teachers explain the importance of social aspects of technology with the process of technology development: Bouras & Albe (2008) described teachers' perception that the society is dependent on technology because of the change of life style requiring more and more new inventions and technical processes. A continued interaction and connection between scientists and technology teachers may need to be established to overcome this conflict (Stein et al., 2006).

Gender

A stereotypical gender difference was observed in the social sub-scale: It is smaller than in the interest sub-scale but still significant. Only in-service teachers in the social sub-scale showed no gender difference. The gender difference was shown only in the younger age groups. The social aspects of technology score positive for both sexes, although Rennie & Jarvis (1995a) reported a more positive perception ratio. In adulthood, the social implications of technology are well balanced although a higher technical interest score of male participants is apparent in all age groups, an unsurprising result, as males always show higher interest in technology. This is in line with Rennie & Jarvis (1995b) and Brown (1993), where the latter reported a gender difference of technology interest even at pre-school ages. Boys for example seemingly prefer to play with technical toys or computer games. If teachers don't pay attention to girls' performance in technical matters, this gender gap remains (Brown, 1993). This stereotypical gender gap for technical matters appears also in other groups, for example in the labor market described by Beede et al. (2011): even women with a STEM (Science, Technology, Engineering and Math) degree are less likely prefer a STEM career, many of them moving to educational or health sectors. Consequently leading to an under-representation of women in STEM careers, although many jobs in the future will be in this sector because of the economic enhancements (Dasgupta & Stout, 2014). The question of the causes of the gender gap remain: Dasgupta & Stout (2014) discussed different stages in the gender gap development: (a) childhood and adolescence, (b) emerging adulthood, and (c) young-to-middle adulthood. During childhood children learn about the general role stereotypes mainly from their parents (Eccles & Jacobs, 1990). Another major influence, particularly in adolescence, is the peer group, where young people learn their first social interactions (Eaton, Mitchell, & Jolley, 1991). Peer groups often choose their members from those in the same courses and those who share similar interests (Riegle-Crumb, Farkas, & Muller, 2006). The next step in the development of the gender gap is in emerging adulthood (Dasgupta & Stout, 2014). Here the question is why girls with an interest in STEM do not proceed to a science carrier. Young woman are generally under-represented in the male-dominated science community, leading to a dominated feeling when meetings are not gender balanced (Murphy, Steele, & Gross, 2007). Another cause may be the lack of models in the STEM community (Dasgupta & Stout, 2014). Female experts acting as role models may overcome this (Stout, Dasgupta, Hunsinger, & McManus, 2011). In adulthood, women have to compete with the male colleagues to demonstrate their equality. Finally, one must not forget the need to combine family and work (Mason & Goulden, 2002). Altogether, there are many reasons for the gender gap in technology and general in STEM related sciences, and many possibilities to bridge Baram-Tsabari & Yarden (2011) see typical stereotypes not manifested until the end of high school. So, an interest preference for technical topics needs to be formed in school in order to bring girls into a corresponding profession. With training in the younger years, the gender gap may disappear. To reduce the gender gap there must be some methods like the interactive strategies from Lorenzo, Crouch, & Mazur (2006) who reported reduction of the gender gap with these strategies.

No doubt, gender gaps need to be reduced. Improved teaching methods and closer inspection of girls' technical interest and skills in school are required to promote girls' interest in technical issues. Technical subjects may become increasingly relevant to girls when they find stimulation in younger classes long before the choice of academic study (Speering & Rennie (1996), Lips(2004). Women often tend to more social motivation, so one way to introduce technology in schools is to increase emphasis on social aspects of technology (Lips, 2004). Reduction of those gaps may bring more young women into professions in technical fields or into research on technical issues (Beede et al., 2011).

Conclusion & Outlook

Applying our questionnaire will not solve the issue. It is simply a step towards illustrating the gender gap in different age groups, and perhaps point to necessary actions to reduce that gap. Frequent validity measures need to secure qualitative in the context of fast development in technology.

More studies may help to evaluate the effect of age development in increasing interest or emphasizing social aspects technology, and may show its potential in integrating more technical issues into everyday lives. As individual interest and social aspects supposedly are influenced by media, currently unknown technical issues may come up. This background knowledge may further support educational authorities to position "Nature and Technique" into early syllabi in order to enrich the related skills of that age group (ISB, 2004). Maybe this combination will better support the preparation of young children for life; nevertheless, this expectation needs further elaboration.

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Compliance with Ethical Standards

Conflict of Interest: The authors declare that they have no conflict of interest. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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5.4 Teilarbeit B

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BIONICS- an out-of-school day in the zoo

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BIONICS- an out-of-school day in the zoo

Abstract

Bionics by definition combines science and technology, with nature acting as a model for technical applications. Bionics is expected to lead to a better understanding of the Nature of Science (NOS). We applied a hands-on inquiry-based module about bionics with 6th graders during a public bionics exhibition in a zoological garden that allowed students to act as researchers, i.e. to understand the problem-solving process and to search for methods to overcome problems. The practice of science and engineering was at the center of this intervention: for example students were asked to provide explanations and design solutions in the bionics field (NGSS, 2017). From this complex field we showed examples using living animals in the zoo. Our students learned bionics topics directly on the living animal by transferring them later to bionics topics. The stream-lined shape of the dolphin snout and the communication system of dolphins and other examples, each with its technical and bionics application were examined. Bionics can serve as a complement to other biology topics. An increase in cognitive knowledge was observed both immediately after intervention, and also after a complete school year. Male participants showed more interest in technology than females.

Key words: bionics, technology, outreach education, zoological garden, exhibition

Introduction

Bionics combines biology and technology to solve technological problems by using nature as a model to apply to man-made solutions (Nachtigall & Wisser, 2013).

One of the most famous bionics examples is the so-called lotus-effect, where plants can keep surfaces absolutely dirt-free even when growing in dirty water: A self-cleaning mechanism using wax-coated surfaces prevents the adhesion of dirt particles in water drops rolling down plant surfaces (Barthlott & Neinhuis, 1997). That nature-inspired discovery has been applied in some para-bionics products (Barthlott, Mail, & Neinhuis, 2016). Another example is the fin ray effect in fish tail fins: the structure of these fins are special in that they do not bend away when you press against the fin, on the contrary the fin bending in pressures direction and so could adapt optimally on the water (Freier, 2014). The arrangement and composition of the rays have recently been adopted in robotic picker arms, because of the structure and the optimal adaption to sensitive objects like lamps (Bannasch & Kniese; 2012). The fin ray effect is an adaption to living in water and could be used in teaching the general biology of fishes or even the morphology of fishes (NGSS, 2017).

A further example is the shark skin effect, adapted in aircraft riblets to substantially reduce air flow resistance (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe, 1997). The parallel ridges on the longitudinal body of a shark, and of an aircraft, also reduce drag (Oeffner & Lauder, 2012). The principle of reducing drag has many examples in bionics: many animals like dolphins, fish or sharks have methods to reduce drag (Campbell, Reece, & Heinisch, 2016). This principle is also often transferred to technology applications like in cars, aircrafts or swimming suits (Dean & Bhushan, 2010).

The teaching of evolution could also include bionics: the homologous development of mammal's extremities is observable in different aquatic animals, while the analogous development of extremities for example could be seen as a bionics challenge as different solutions for similar problems exist (Campbell et al., 2016). Animal morphology and the adaption of animals could be connected with bionics. Another example for adaption is different skin types of aquatic animals: fish, birds, reptiles and nearly all other animate being found solutions to adapt to live in the water (Campbell et al., 2016).

Phenomena of nature have inspired technicians to adjust or improve technology applications by adapting effects in the technological world. Nature has always found solutions for its problems and so could be seen as a source of inspiration for bionics. Bionics could be included in many other biology curriculum topics. Those innovative topics need promotion in school classrooms to improve the motivation for science and technology (Neurohr & Dragomirescu, 2007). Innovative topics need innovative school learning environments like cooperative working to enrich students' perceptions.

Johnson & Johnson (1994) explained cooperative learning as permitting groups of students to form by letting them talk to each other. A meta-analysis of 65 studies reported considerably better cognitive achievement and higher attitude scores in cooperative learning (Kyndt et al., 2013), hence our bionics intervention focused on cooperative learning in combination with hands-on learning.

Student Objectives

We anticipate that participating students will learn to understand the procedural method of bionics, to identify bionics in general, and to know some specific examples of bionics. Bionics principles are generally represented using the "Lusinus-method": research of nature is followed by abstraction of a biology principle and the implementation of this principle in technical applications (Nachtigall, 2010). The principles and mechanisms of bionics require understanding the scientific background and the principle of transferability to daily lives.

Details of intervention and exercise

The intervention required five school lessons, which are divided in different time slots and phases. The introduction phase takes barley one school lesson and each module at least two school lessons (see table 1). To assure similar pre-knowledge, a pre-group introductory phase was provided focusing on the basics of bionics, biology and technology (Appendix A, workbook p.4).

Tab. 1 Module phases and description

phase of teaching	*Description*	*students activity*	*Time (min)*
pre-group phase	Introduction into bionics	teacher-guided learning	25
module 1 (seminar room module)	seminar room activity in a seminar room	hands-on learning at stations	85
module 2 (aquarium module)	Aquarium activity concentrating on the living animal	hands-on learning at stations	85

Both the seminar room and the aquarium modules were applied as hands-on stations employing with cooperative learning. Teachers simply supervised from the background and only responded to student questions on request. The group-work phase was self-explanatory but guided by a work book, which the students received at the module's start. Both module parts were completed in a zoological garden (Figure 1). A list with all necessary materials for the intervention is attached (Appendix J) as well as the workbook, where the students have to fill in the work orders (Appendix K).

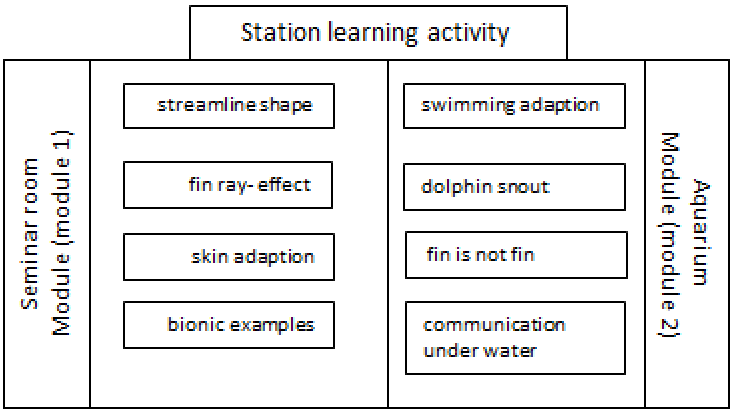


Fig. 1 Different stations of the group work seminar room module and aquarium module

Seminar room module (also possible in a normal classroom)

Different bionics examples incorporated the stream-lined shape, the fin-ray effect and skin adaptions, including the shark skin effect (Figure 2).

Figure 2a & b: Learning in seminar room module (Landesamt für Umwelt, 2015)

Station Bionics Examples

An instruction sheet with a short introductory text about biology models and bionics applications described self-sharpening knives/rodents, gecko-foot/glue, lotus-effect/glasses, bird-wings/winglets, honeycomb/ washing machines, bones/Eiffel tower as well as velcro fruits/ hook-and-loop fastener (Appendix B, workbook p.5). 14 pictures aligned with short texts (on the right the bionics application, on the left the biology model). Underneath an example is shown, the rest is attached in the appendix section.

Organizing Pictures

Nature Model		Technology Application
Picture of Velcro fruit	Georges de Mestral came up with the idea of fur the Velcro closure on walks with his dog. In the dogs were always Velcro fruits, which caught themselves there. After this model he designed the first velcro fastener.	Picture of Velcro fastener

Figure 3: Example of the Velcro fastener and the Velcro fruit in the organizing picture station.

Station Streamline shape

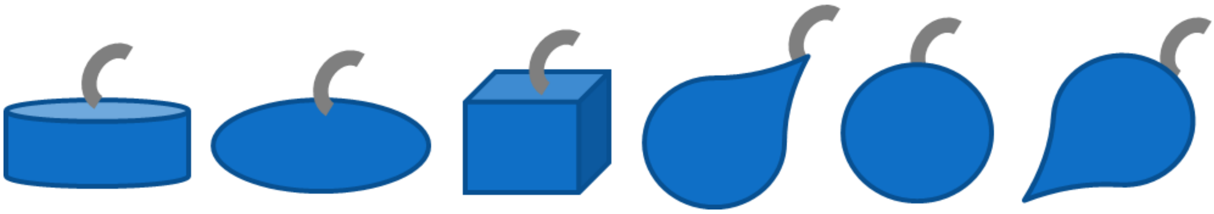


Figure 4: Different formed objects for the streamline experiment.

Different shapes such as a bowl, a cuboid, a cube or the streamline shape formed of wax (Figure 4) were to be arranged according to streamline adaptations (workbook p.6f). For that experiment, a glass cylinder of water with several marking points was supplied; above that cylinder different objects were fixes consecutively (Figure 5a,b). The other side of the string was held by tension, so that the starting point of the object is in the right position (Figure 5c). Objects were then dropped into the water (Figure 5d) and a second student marked the depth the object reached (Figure 5e,f). Each experiment was repeated three times in order to register the deepest immersion and hence the lowest resistance (Figure 5f).

Figure 5: Experiment implementation; a: Fixation tower, b: objects fixation, c: starting point, d: falling of objects, e: marking of depth, f: measuring of depth.

Station Fin ray-effect

First a short information sheet about the phenomena in general and a model of the fin-ray effect was presented (Figure 6, Appendix C, workbook p.11).

Figure 6: simplified schema of the fin-ray effect

Afterwards three models were presented; each model was differently constructed but always containing the fin-ray effect (Figure 7a). One model had no stabilizer, the second had one and the third had several stabilizers. When pushing against the model (Figure 7b) with the trigger finger, students can easily recognize function of the stabilizer.

Figure 7a: 3 different constructed fin models; 7b: fin-model with many stabilizers; 7c: model of picker arms with the fin ray-effect.

An example of a bionics application of this effect is seen in different picker arms in the industry. This system is also reconstructed as a model, where the students could test the picker arms by lifting a ball (Figure 7c).

Station Skin adaption

Skin examples of different water animals, concentrating on shark skin, bird feathers, or fish slime layers illustrate adaptation strategies and bionics applications of the various strategies (workbook p.14). A variety of examples represent animal skin (feather, sandpaper, mucus), and drawings of the animals to be assigned correctly to the appropriate skin (Figure 8).

Figure 8: Assigning animal models (fish, penguin, shark) to skin models (feather, sandpaper, mucus).

Information text (Appendix D) and pictures (Figure 9) explain the bionics application of the shark skin effect.

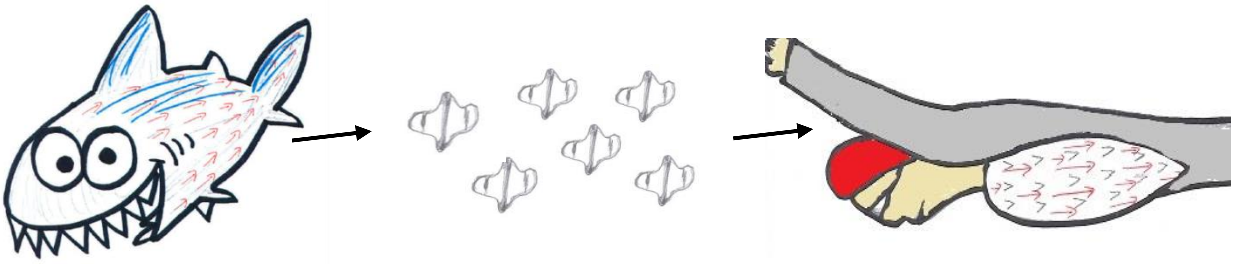


Figure 9: Bionics application of the shark-skin effect.

Aquarium module

Adaptations of living animals (dolphins, seals, fish and manatees) were identified and observed, in particular the swimming adaption, the dolphin snout, fins and communication skills (Figure 10).

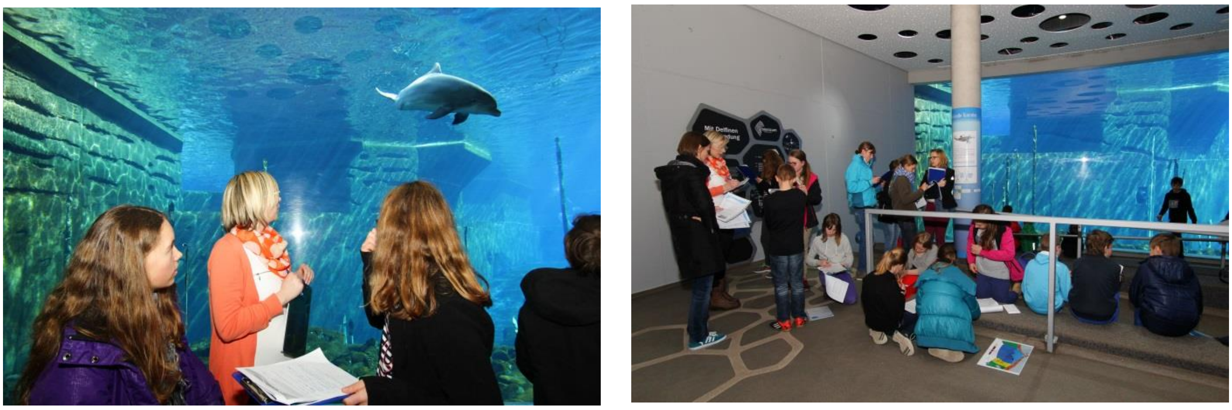


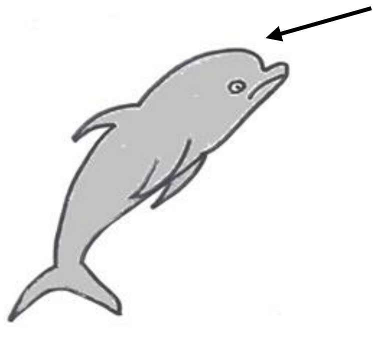
Figure 10 a & b: Learning in Aquarium-module (Landesamt für Umwelt, 2015).

Station swimming adaption

A first task focused on the stream-lined shape and swimming speed (workbook p.8). The fastest swimmer was identified. Additionally, students were required to define nutrition preferences, whether animals live as herbivores or carnivores.

Station Dolphin snout

The dolphin snout was observed by completion of a drawing (Figure 11a). This drawing was to be compared with a picture of a tanker (Figure 11b).



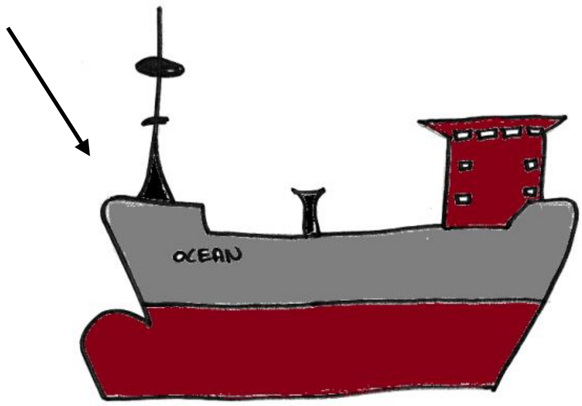
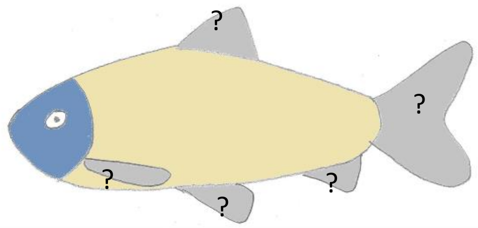


Figure 11a: Drawing of a dolphin head, 11b: Bionics application of dolphin snout in a tanker.

An information text (Appendix E) explained the parallel of tanker shapes and dolphin snouts as an adaption to reduce water flow drag and save energy (workbook p.9).

Fin is not fin

Fins of different animals had to be labeled and assigned to a living animal in the aquaria (Figure 12a, b) (workbook p.10). Students were also required to draw their own hand next to a picture of the dolphin's flapper in their guiding book in order to show homologies of evolution.



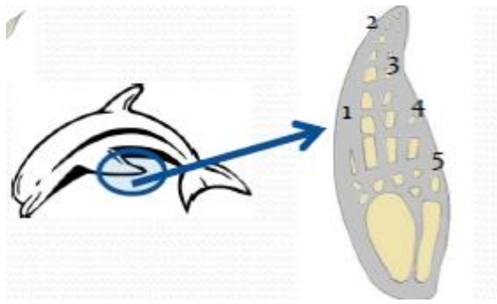
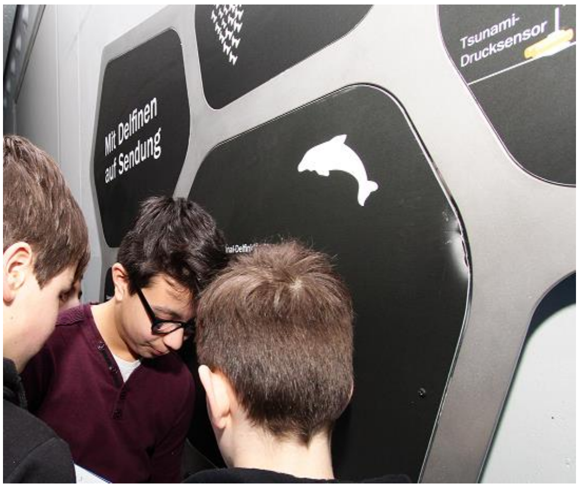


Figure 12a: Drawing of a fish, 12b: Dolphins fin

Communication under Water

This station dealt with the communication system of dolphins and its technological application in the tsunami early warning system (workbook p.12f). The students could hear the voices of the dolphins in a hearing station (Figure 13a).



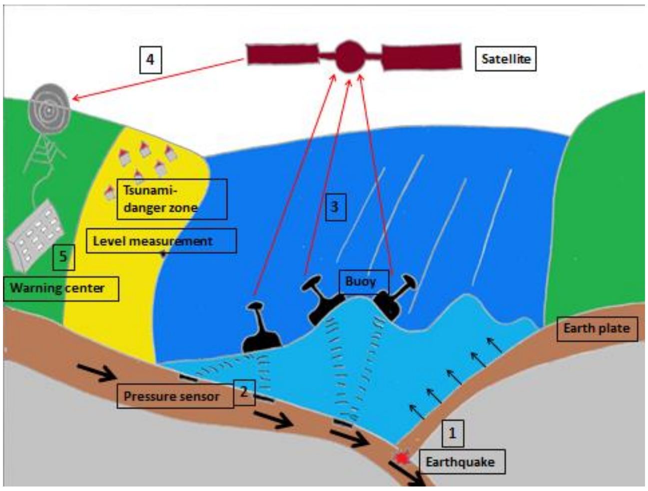


Figure 13a: Hearing station of dolphin's communication (Landesamt für Umwelt, 2015)**;**
13b: Simplified schema of the tsunami early warning system

Subsequently an information sheet (Appendix F) simplified the model of the early warning system for tsunamis, showing pressure sensors on the sea bed sending information to a buoy at the ocean surface, which also uses the technology of dolphin communication (Figure 13b).

Alignment of intervention with Next Generation Science Standards (NGSS)

The described intervention in a zoo meets several of the Next Generation Science Standards (NGSS). All three main dimensions of the NGSS are involved: the crosscutting concepts (cause and effect), science and engineering practices (developing and using models, constructing explanations and designing solutions) and disciplinary core ideas (information processing, energy in chemical process and everyday life) (Next Generation Science Standards, 2017). Participants learn about the practices of scientists and engineers in coming up with inventions in the crosscutting field of bionics. Students acquire knowledge which they apply to deepen their crosscutting concepts and broaden their ideas in different scientific fields like biology, technology and bionics. Especially the relationships between science, technology, society and the environment and their influence on the natural world are central to our intervention.

Further research reading

Our research group also focused on different research questions with this intervention:

First, knowledge acquisition due to program participation peaked directly after and dropped six weeks later, but never fell back to pre-knowledge levels (Marth & Bogner, 2017a). Even after periods of twelve weeks and one year this pattern remained stable. We have designed a knowledge questionnaire for the testing the acquisition in a pre- and post-testing design (Appendix G).

Secondly, motivation was assumed to be a major reason for participation: two originally hypothesized factors (intrinsic motivation and self-efficacy) merged into one (self-confidence) (Marth & Bogner, 2017b)(Appendix H). SC peaked directly after participation, but failed to sustain over a six week time period. No gender differences were observed at any point. Science motivation and technology interest correlated at a low level.

Thirdly, interest in technology and the social implications of technology in different age groups was a major factor in our bionics learning module (Marth & Bogner 2017c)(Appendix I). We applied an existing scale to 610 participants (students, university freshmen, and teachers) and confirmed the structure of the Technology Questionnaire (Rennie & Jarvis, 1995). Gender differences occurred in all age groups in interest of technology in that way that male participants show more interest as their female counterparts.

Conclusion

Our intervention combined biology, technology and bionics as subjects, and applied cooperative learning in group working and station-guided learning. Our station-guided learning included a classroom module, and could be integrated in the NGSS and permitted teaching practices in school. The aquarium module is a specific outreach zoo module with living animals (dolphins and fishes). The students enjoyed the field days in the zoo and also acquired knowledge and science motivation as Marth & Bogner (2017 a, b, c) have shown. Finally we think that this intervention or variations of it should be available to different classrooms and for all types of students.

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Appendix A: Pre-group phase with an introduction into bionics field

What is BIONICS?

Biology **Technology**

Bionics is the combination of biology and technology. Nature (biology) has solved many difficult tasks in the course of its development perfectly. "Bionics researchers" take a close look at nature and investigate how nature can be used technically. Many improvements can be achieved or new inventions can be made.

<u>Pioneers of Bionics</u>

<u>1. Leonardo Da Vinci (1452- 1519)</u>

- He dealt with the dream of flying and designed a variety of aircraft which finally proved to be incapable of flight.
- He made plans for a rotor flying machine with a helical air screw, which was supposedly inspired by the spirals of the fruits of bur clover.
- This aircraft can be regarded as a forerunner of today's helicopters.

<u>2. Otto Lilienthal (1848-1896)</u>

- Lilienthal was initially fascinated by the gliding of white storks.
- He recognized the reason for the effortless glide of the birds.
- The arched wing shape creates buoyancy. With this realization he constructed wings, which he tested in numerous experiments.
- When he was certain that his wings, as well as the biological role model, produced buoyancy, he began to build his first glide aircraft.

Appendix B: Station Bionics examples

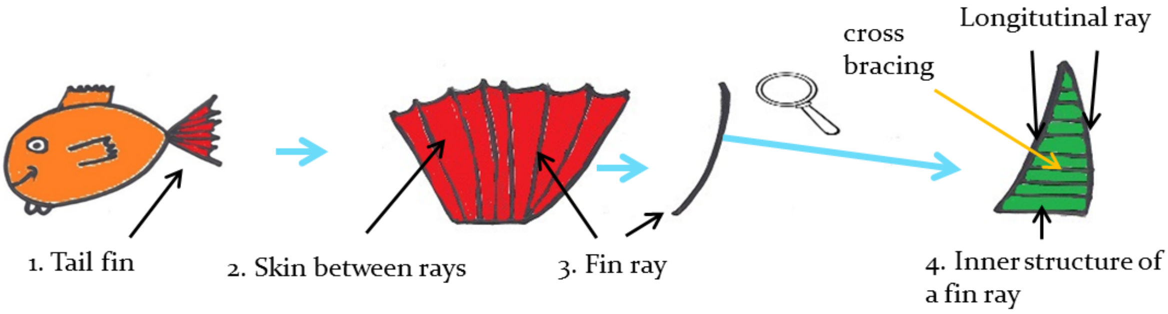
BIONICS: Inventions of nature

Organizing Pictures

Nature model		**Technology Application**
Picture of velcro fruit	Georges de Mestral came up with the idea of the velcro closure on walks with his dog. In the dogs fur were always Velcro fruits, which caught themselves there. After this model he designed the first velcro fastener.	Picture of velcro fastener
Picture of lotus plant	Some plants have a self-cleaning effect, the so-called lotus effect. With this effect, the water bubbles off its leaves by incorporation dirt particles. This effect is used in the automotive industry and in spectacle lenses.	Picture of lotus application in glasses
Picture of gecko	Due to the special structure of the foot soles, the geckos can be easily climbed along virtually all surfaces. The gecko-adhere principle is based on certain chemical forces between the soles of the feet and the respective surface. This principle above is used for gluing.	Picture of glue
Picture of honey comb	The honeycomb structure is hexagonal and therefore very stable and also space-saving. The principle of the honeycomb structure is therefore often used in lightweight construction. An example of this would be pressed metal boards.	Picture of hexagonal metal board
Picture of eagle	When wings are spread apart, several smaller vertebrae are produced in the air. At certain points, the small swirls cancel out each other, so that the flow resistance is reduced. This allows some birds to fly with less energy. In aircraft, the phenomenon is implemented with "winglets“ on the aircraft wings.	Picture of winglets in aircraft
Picture of rodent	The teeth of rodents grow for lifetime. They sharpen themselves, since they are continually used for gnawing. This principle is also used with self-sharpening knives. These can not grow, but are able to sharpen themselves.	Picture of knife
Picture of bones	The structure of the bones is often used as a model for stability in buildings. The special structure not only gives the bone, but also the Eiffel Tower its extreme stability.	Picture of eifel tower

Appendix C: Station Fin ray-effect

Bionics of the fin ray-effect



- The tail fin (1) consists of many rays (3.), connected by skin (2.).
- The fin ray effect is achieved by the special structure of the fins. The fin ray (3.) consists of two cartilaginous longitudinal beams, connected by flexible material (cross braces) (4.). The longitudinal beams can move relative to one another, and their distance is always maintained.
- The tail fins of fishes are highly interesting. If you press your finger against them, they do not bend away. On the contrary, the tail fin bends toward the finger. It adapts to the finger (5). This phenomenon of fitting the fin is called fin ray effect.

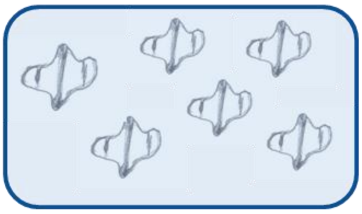
5. Tail fin against which a finger is pressed

- The adapted shape change of the fin allows the fish to have a highly efficient movement in the water. The technical design is a triangle of flexible longitudinal and transverse struts which are elastically connected to one another, similar to the one shown in Figure 4.

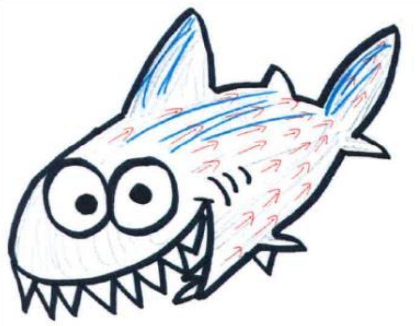
Appendix D: Station bionics of shark-skin

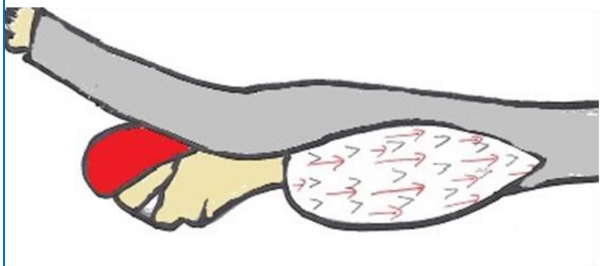
Bionics of shark-skin

The whole surface of the shark skin consists of tiny teeth. They help the shark to save energy. The microscopically small teeth are all Straightened to the tail fin of the animal.



The water flowing is channeled and the friction resistance is reduced.





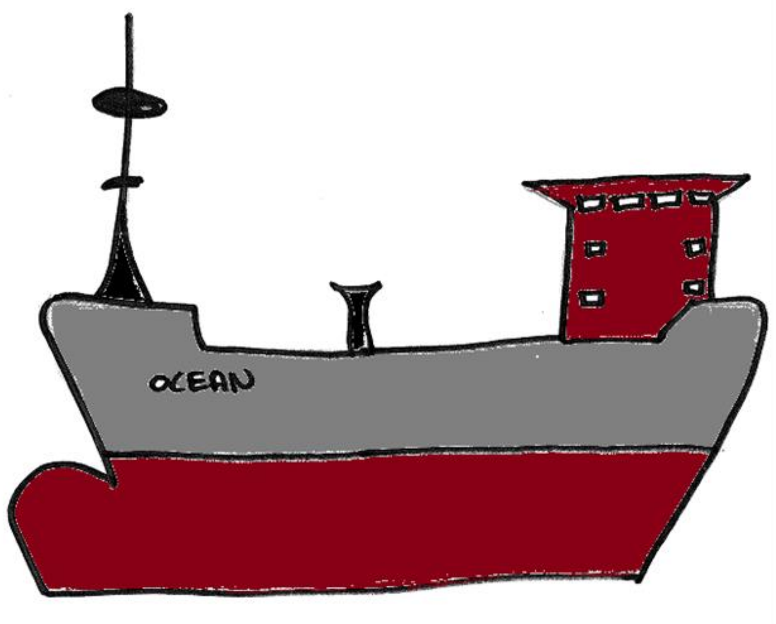
This knowledge is also used by competitive swimmers. They wear very special suits, which have a grooved structure like the shark skin.

These types of surfaces can be used where optimization of flow behavior is required.

For years an aircraft manufacturer has experimented with an artificial shark skin for the wings of the machines to save fuel.

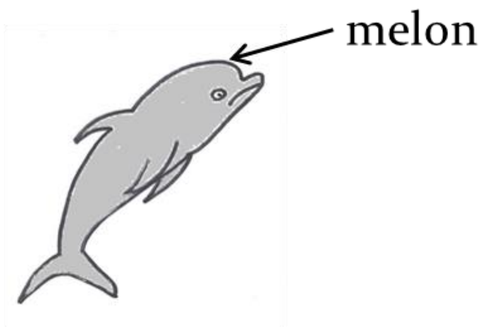
Appendix E: Station dolphin snout

Bionics of the dolphin snout



The mouth of a dolphin forms a distinct beak.
Also characteristic is the melon, which bulges.
“Melon” denotes the space under the forehead.

However, since this bulging is also visible on the outside, “melon” is often used synonymously with forehead.
When the dolphin swims, the beak and forehead divide the water so that high speeds even with little energy consumption are possible.



With this striking forehead, the dolphin has become something like the prototype of bionics, because its snout served as a model for the pear-shaped bow attachment on ships. The best examples for this are large oil tanks.

Flow technicians have found that ships run faster and consume less fuel when their bow is modeled on the dolphin's head.
The fuel savings of the ships is so high, that even in older ships this "nose" was often retrofitted.

Appendix F: Station dolphin communication

Communications of dolphins : 2 Signals

Simplified model:

- 1 signal for information

  "I'm here. Fish are in the East "
- 1 additional signal for melody

  "Born to be wild“
- Now if "I am in the East, fish are here" sounds at the same time as "Wild to be born", then dolphins can decrypt the information, and turn this coded information "around" and decrypt it.
- This type of communication is also used in the case of tsunami detection in special pressure sensors.

Appendix G: Knowledge questionnaire (self-designed)

Module	***Example Questions***	
Aquarium-Module	Dolphins uses for their communication: a) A signal analogous to the human voice. b) It’s ears. c) A signal that does not occur in nature a second time. d) A combination of different signals. (C)	What kind of bionics application employs the communication system of dolphins? a) underwater communication of divers b) tsunami pre-warning system (C) c) aircraft system in airplanes d) radio frequency
	The dolphin's fin structure is the same as by ...? a) dinosaur.. b) reptiles. c) mammals. (C) d) d) fishes.	The mucus –ridden layer of the fish serves the ? a) better movement in the water (C) b) defense against human enemies c) camouflage d) reproduction
	Why is the dolphin a fast swimmer …? a) because it is a very shy animal. b) because it's a prey. (C) c) because it has many animal enemies. d) because he has to escape.	The "dolphin snout" is most commonly found at ...? a) Cruise ships. b) Tankers. (C) c) Sailboats. d) Pirate ships.
	By a pear-shaped bow, ships ...? a) save fuel. (C) b) give out a warning for dolphins. c) accumulated fuel. d) improve the outward appearance.	What element is transferred to the pear-shaped tower on ships? a) The principle of the sonar system of dolphins. b) The construction of the dolphin's mouth? (C) c) The resemblance of the fin shape. d) The communication of dolphins.
	Which communication medium do dolphins use? a) Ears b) Lateral line organ c) Sonar (C) d) Whiskers	With the Fin Ray effect, ... is transferred to the technical application. a) Each component b) Surface structure c) Substance d) Principle (C)

Module	*Example Questions*	
Seminar room-Module	What is the lotus effect? Plants ... a) capturing small flies. b) protected from parasites by glue. c) with very shinny surface due to waxes. d) with water-repellent. (C)	Rodent teeth are a bionics model for… a) forks. b) knives. (C) c) plates. d) teeth washing.
	Why can geckos almost everywhere hold on? a) because it has adhesive on the feet. b) because it is quite weight light. c) because it has a special structure of the footplates. (C) d) because he has claws to hold.	The Eiffel Tower in Paris is bionicaly imitated by … a) fingers. b) bones. (C) c) brawn. d) nerves.
	What is the benefit of a bionicaly optimized component modeled on the "fin ray effect"? a) it adapts flexibly to any object. (C) b) it remains rigid. c) it deforms after strong pressure exertion. d) it remains exactly as it is.	The Fin Ray effect finds application in the ...? a) robotics. (C) b) aerodynamics. c) kinetics. d) motor activity.
	The hook-and-pile fastener is an bionics example inspired by ? a) blossom b) flower stalk c) fruit (C) d) leaf	How is the shark skin built up? a) from many small sheds. b) from many small teeth. (C) c) from a mucus-ridden layer d) from many small hairs.
	What is bionics in the shark skin-effect? a) the operation. b) the motor skills c) the form d) the surface structure. (C)	The bionics of the shark skin find application at? a) caps. b) wellington boots. c) swimming suits. (C) d) jackets.

Module	***Example Questions***	
Combination Module Questions from the whole day	If someone wants to make a bionics invention, he needs to be... a) an engineer. b) inspired by nature. (C) c) especially smart. d) inspired by art.	Bionics is... a) a sustainable technology. b) a technology for organic food production. c) idea transfer from nature to technology. (C) d) technology from a biological point of view.
	The streamline shape is a central research area in bionics because ...? a) many buildings correspond to this form. b) the flow characteristics are improved. (C) c) whose principle of effectiveness can exhaust whole houses. d) the surface structure is used in the construction of modern cars	Bionics is composed of the following words: (9) a) biology and robotics b) biology and technology (C) c) biology and nickel d) biology and gothic
	The streamlined shape has an ideal ……..shape. a) spherical b) drop-shaped (C) c) box-shaped d) elongated	The biological phenomenon of the streamlined form is applied to ...? a) hook-and-pile fastener b) optimized components. (C) c) technical grippers d) buildings.
	Which animals have the Fin Ray effect? a) reptiles. b) mammals. c) fishes. (C) d) birds.	What species of animal has breast-, back-, belly-, anal and tai- fin? a) Dolphin b) Sea lion c) Manatee d) Trout (C)
	The streamline shape …? a) doubles the resistance. b) increases the resistance. c) clears the resistance. d) minimized the resistance (C)	In which bionic example is the form transferred to the technical application? a) Ventilation systems based on the termites b) Fin ray effect (C) c) Gecko- adhesion principle d) Shark-skin-effect

Appendix H: revised Science Motivation Questionnaire (Marth & Bogner, 2017c)

Factor 1: Self-confidence
2 I am curious about discoveries in science
3 The science I learn is relevant to my life
4 Learning Science makes my life more meaningful
5 I enjoy learning science
6 I believe I can earn a grade of “A” in science
7 I am confident I will do well on science tests
8 I believe I can master science knowledge and skills
9 I am sure I can understand science
10 I am confident I will do well on science labs and projects
Factor 2: Grade Motivation
11 Scoring high on science test and labs matters to me
12 It is important that I get an “A” in science
13 I think about the grade I will get in science
14 Getting a good science grade is important to me
15 I like to do better than other students on science tests

Appendix I: Technology Questionnaire Part B (Rennie & Jarvis, 1995).

Interest	
I1	I am interested in technology.
I2	I would like to learn more about technology.
I3	I would like a career in technology later on.
I4	I like to read books and magazines about technology.
I5	I would like to join a hobby club about technology.
Social	
S1	Technology makes the world a better place to live in.
S2	Technology has brought more good things than bad things.
S3	It is worth spending money on technology.
S4	Inventions in technology are doing more good than harm.
S5	Technology is needed by everybody.

Appendix J: List of Materials for every single station

List of Materials for the BIONICS-Module:

Introduction: What is bionics?

Materials:

- *Exercise sheet (workbook 1a.)*
- *Information sheet (Appendix A)*

Station Bionics Examples:

Materials:

- *Exercise sheet (workbook 1b.)*
- *Poster (Appendix B)*
- *Pictures of the natural model and the technical application of bionics examples (google)*

Station streamline shape

Materials:

- *Experiment pictures (Figure 5)*
- *Exercise sheet (workbook 2a.)*
- *cylinder, lifting block, string*
- *wax forms (Figure 4)*
- *ruler*

Station swimming adaption

Materials:

- *Exercise sheet (workbook 2b.)*
- *Animals in aquaria*

Station dolphin snout

Materials:

- *Exercise sheet (workbook 2c.)*
- *Information sheet „Dolphinsnout“ (Appendix E)*
- *Animals in aquaria*

Station fin is not fin

Materials:

- *Exercise sheet (workbook 3a.)*
- *Animals in aquaria*

Station Fin Ray-Effect

Materials:

- *Exercise sheet (workbook 3b.)*
- *Experiment description (Appendix C)*
- *Model Fin Ray-Effect (Figure 7)*
    - *Creation of the Models: handicraft work (google)*
    - *Buying: Festo Germany has 3D-Modells*
- *Fish tail*
- *Ping-pong*

Station communication under water

Materials:

- *Exercise sheet (workbook 4.)*
- *Information sheet (Appendix F)*
- *schema of the tsunami pre-warning system (Figure 13b)*
- *Animals in aquaria*
- *Hearing station (Figure 13a)*

Station skin adaption

Materials:

- *Exercise sheet (workbook 5.)*
- *Information sheet (Appendix D)*
- *Feather , sandpaper, slime*
- *Drawing of animals (Figure 8)*

5.5 Teilarbeit C

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Does the issue of bionics within a student-centered, zoological garden module generate long-term knowledge?

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Does the issue of bionics within a student-centered inquiry-based learning module generate long-term knowledge?

Abstract

Our educational module focused on selected bionics examples linking the basis of technology to biology. 324 students participated in an outreach intervention in a zoo. We monitored individual knowledge acquisition at three testing points: two weeks before (T0), immediately after (T1) and six weeks (T2) after participation. We monitored a subsample of 191 for longer (twelve weeks (T3) and one year (T4) later). Our module consisted of two units, a seminar room module and an aquarium module with living animals. As expected, knowledge peaked directly after program participation and dropped back after six weeks, but never fell as low as prior knowledge. Even one year later, the knowledge level remained constant at the level reached six weeks after participation. Prior knowledge was shown to be dependent on technology interest and social implication scores before participation.

Keywords: program evaluation; student evaluation; long-term knowledge; technology interest; bionics

Introduction

Technology today is present everywhere (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). The young generation grows up in a technical world including social media and communication technology (O'Keeffe & Clarke-Pearson, 2011). Although policy makers and commercial companies require a level of technological education, our society largely regards technology negatively (Ardies, De Maeyer, & David Gijbels, 2013). Therefore it is important that even young students be motivated for and interested in technology and science. For that it's necessary to show the prior knowledge of technology interest and social aspects of technology (Rennie & Jarvis, 1995). Thereupon students will become more favorable in science, when they make acquisitions with positive feelings and experiences in scientific fields (Akpınar, Yıldız, Tatar, & Ergin, 2009). Teachers often regard technology as an applied science with potential for social transformation, and for connecting science, society and technology (Bouras & Albe, 2008). It is this connection between technology and science that is for importance in the present study. George (2006) described young students as higher scoring in usability of technology and pointed to a transitional passage from primary to secondary school and to the need of motivation for science and technology. Secondary school students often have other expectations of science with motivational consequences effect upon long-term career choices. During a school career reduction of positive attitudes towards science have often been recorded (Speering & Rennie, 1996). To overcome this, teachers and teacher educators need to broaden their experience to promote positive attitudes to science in the transition from primary to secondary school (Mc Robbie, 2000). For this reason, it is necessary to develop appropriate educational programs. In general, innovative topics are assumed to promote students' interest in science (Marth & Bogner, 2017).

Bionics linking Technology and Science in classroom

Bionics is a research field which improves technical applications including the biology and technology point of views to find appropriate solutions and provides many examples of how nature can act as a source of technical solutions (Nachtigall & Wisser, 2013). As a new science field, it has produced numerous inventions and raised expectations for the next decade: the lotus-effect is one of the best knowns examples, where surfaces remain dirt-free although they grow in sludgy water. A self-cleaning mechanism based on a wax-coated, bumped surface has been identified as the reason for this, as such surfaces produce rolls of water that wipe away any dirt (Neinhuis & Barthlott, 1997). The lotus-effect has been adapted to produce some para-bionics products (Barthlott, Mail, & Neinhuis, 2016). Another example is shark skin, whose exiguous parallel ridges on a longitudinal body axis dramatically reduce drag (Oeffner & Lauder, 2012). Riblets adapted to shark skin ridges are used on aircraft to reduce air flow resistances (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe 1997). Archetypes in nature have inspired technicians to improve existing technology by copying and/or adjusting master plans of nature. New and interesting phenomena in nature have inspired technicians to improve existing technology and build up new inventions. Bringing this relevance of bionics into classrooms may motivate students towards science and technology (Neurohr & Dragomirescu, 2007).

Knowledge

Teaching is a very complex and exhausting duty as Mishra & Koehler (2006) have explained. A central dimension of teaching is knowledge: as traditionally content knowledge is required of almost all school curricula and is defined as the “amount and organization of knowledge per se” (Shulman, 1986, S.9). The learning outcomes are subject contents and also “a description of what is to be done with or to that content” (Krathwohl, 2002, S.213). Knowledge has also many other types such as pedagogical content knowledge. Teachers have to understand the difficulties and possibilities of content learning including different preconceptions such as students’ age, origin or cognitive abilities (Shulman, 1986). Pedagogical content knowledge is more than straight content knowledge, the teachers also need appropriate educational practices, which are represented in pedagogical knowledge. A third type of knowledge is technology knowledge, because “technologies have come to the forefront of educational discourse primarily because of the availability of a range of new, primarily digital, technologies and requirements” (Mishra & Koehler, 2006, S.1023). The

Mishra & Koehler (2006) study suggests a connection between content, pedagogy and technological knowledge which is necessary for good teaching. The teachers have to consider these three dimensions when constructing learning environments. The pedagogical, technological knowledge of teachers helps to provide appropriate content knowledge, which could also assigned to the different domains as Bildungsrat (1970) suggested: reproduction, the repetition of straight content knowledge as taught; reorganization, students' capacity to rearrange newly acquired knowledge; transfer, where common principles are transferred to similar concepts; and problem solving, where students use acquired knowledge to approach new problems. We focused on reproduction, reorganization and the transfer of content knowledge.

Surprisingly, students' knowledge acquisition is not necessarily dependent upon the duration of modules. Even half-day programs produce sustainable knowledge increase, as Fremerey & Bogner (2014) have shown in the context of a drinking water module. Schmid & Bogner (2015) had described similar results in a module of three consecutive lessons. Long-lasting knowledge is of interest to all studies independently of program duration: One-day or half-day programs are expected to show the best possibilities with the curriculum circumstances, where limited time forces teachers to employ short-time interventions. Differing teaching methods play an important role in the acquisition of long-term knowledge as Beers & Bowden (2005) has shown for problem-based learning. Bogner (1998), for instance, demonstrated that long-term knowledge gains produced by week-long programs may persist for a half year. Farmer, Knapp, & Benton (2007) have also demonstrated long-term effects for environmental education school field trip one year after intervention.

Cooperative learning

Cooperative learning is more than putting a group of students together and letting them talk to each (Johnson & Johnson, 1994). There are five conditions under which cooperative learning shows positive effects: “1. Clearly perceived positive interdependence, 2. Considerable promotive (face-to-face) interaction, 3. Clearly perceived individual accountability and personal responsibility to achieve the group’s goals, 4. Frequent use of the relevant interpersonal and small-group skills, 5. Frequent and regular group processing of current functioning to improve the group’s future effectiveness” (Johnson & Johnson, 1994, S.32).

Cooperative learning in pairs or small groups seems to yield better achievement than individual learning scenarios: paired groups, for example, show better self-esteem (Bertucci, Conte, Johnson, & Johnson, 2010). The combination of hands-on and cooperative learning may generate better results compared to control classes (Bilgin, 2006). A meta-analysis of 65 studies in the context of cooperative learning showed both positive cooperation and better cognitive achievement and attitudes (Kyndt et al., 2013). We selected a cooperative learning approach where peers can motivate each other, potentially helping the low interest scorer to be motivated by a classmate. Studies of cooperative learning in a zoo are rare in the literature. For instance, Sattler & Bogner (2016) monitored knowledge increase in a cooperative learning scenario at a zoo, where work stations discussing marine mammals showed a knowledge increase directly after participation, followed by a decrease six weeks later. A cooperative learning scenario at a zoo in combination with the topic of bionics issue offers the potential to increase knowledge and interest in science and technology in general.

Research Goals

The present study focused on the cognitive achievement of a short-time cooperative learning program about bionics at a zoo. The objectives of our study were: (I) to analyze the change in knowledge in the total module and the sub-modules (II), to analyse the long-term effects over one year, (III) to examine the relationship between knowledge acquisition and individual technology preferences.

Methods

Intervention design and context

The bionics module required five school lessons (225 min) including completing a final survey (table 1). All interventions were guided by the same teacher and the same tutor (university employees), and followed the same agenda. To ensure similar initial knowledge levels at the beginning the bionics module, a teacher-guided pre-group introductory phase focused on bionics and selected issues about bionics, biology and technology.

The following module parts (seminar room and aquarium modules) were cooperative learning forms, with students working in groups of 3 or 4. Teachers merely supervised in the background and answered student questions on request. The group work in the seminar room and the aquarium module was self-explanatory, with hands-on work stations guided by a work book, issued to every student at the beginning of the program. The seminar room module was conducted in a special classroom in the zoo and the aquarium module was held at the aquaria in the zoo. Both modules used several workstations, four in the seminar room module and four in the aquarium module (Figure 1). Students were free to choose the sequence of stations, subject to availability.

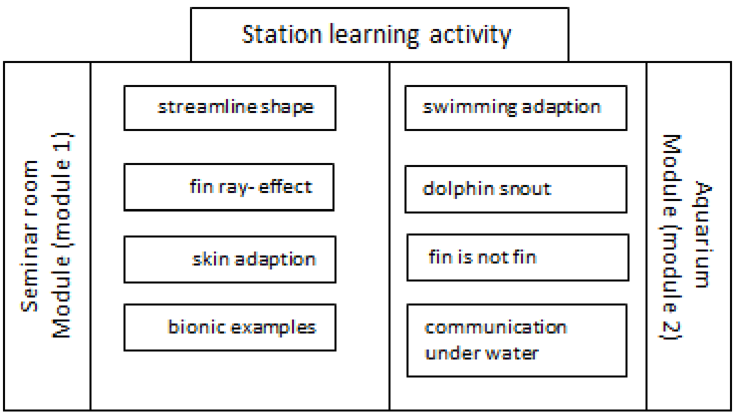

Fig. 1: Different stations of the group work seminar room module and aquarium module.

Seminar room module

In the seminar room module (in the zoo), students learned about streamline shapes of selected water animals by performing an experiment with different shapes such as a bowl, a cube or the streamline shape. Subsequent analyses with an immersion gauge head to measure the depth led to conclusions about streamline adaptations and adapted techniques in cars or aircraft. Other hands-on experiment stations dealt with the Fin-Ray-effect in the tail fins of fish (Appendix C), or with skin examples of a variety of water animals, concentrating on shark skin, bird feathers, or fish slime layers by pointing to adaptation strategies and the bionics application of the various strategies. Another station with different examples of prominent bionics applications showed the diversity of technology which were asked in the TQ (Rennie & Jarvis, 1995).

Aquarium module

The aquarium module dealt with dolphins, seals, fishes and manatees. Students learned directly from original objects but also made real experiences with learning objects (Appendix B). Different stations dealt with bionics examples of dolphins, especially the tsunami pre-warning system and the bulbous bow of big tankers, simulating the sonar system and the dolphin snout. The sonar system and the bionics application of the tsunami pre-warning system were compared at an auditoria station where students could follow scientists' thoughts and the transfer to technical applications. Another example was the vibrissae of seals, a bionics adaptation of which is applied in antennae. The main subject of the aquarium stations was living animals and direct bionics implementations.

A subsequent post-group phase integrated the public exhibition "Bionicum", directly affiliated with the zoo, where hands-on stations, experiments, computer-guided learning, movies (for instance about a robot) elaborated and further explained bionics issues: For example, a video animation presented the principle of rodent self-sharpening teeth and its bionics application of self-sharpening knives. An iron sheet model of the hexagonal construction of the honey comb was compared to bionics adaptations in washing machines. Finally, a robot demonstrated its “human” properties such as dancing, walking and even speaking to visitors.

Tab. 1: Module phases and description.

Phase of teaching	**Description**	**Students activity**	**Time (Minutes)**
pre-group phase	introduction	teacher-guided learning	25
module 1 (seminar room module)	seminar room task	hands-on learning in groups	85
module 2 (aquarium module)	concentrating on the living animal directly on the zoo enclosure	hands-on learning in groups	85
post-group phase	exhibition „BIONICUM“	example of informal learning	30

Sample and study design

324 Bavarian 6th graders participated in a bionics module in a zoo (age *M*=12.2 years, 189 girls, 135 boys). To monitor pre-knowledge, participants completed a test and the Technology Questionnaire two weeks prior to the program (T0). Bionics is an interdisciplinary field between technology, biology and science, so it is important to know whether students were interested in technology. Part B of the TQ (Léonie J. Rennie & Jarvis, 1995) contributed two subscales: interest (5) and social implication (5) (Appendix A). Directly after the intervention, a post-knowledge test (T1) was completed; a retention test followed after six weeks (T2). A

subsample (n=191) completed two more tests after twelve weeks (T3) and one year (T4) (Figure2).

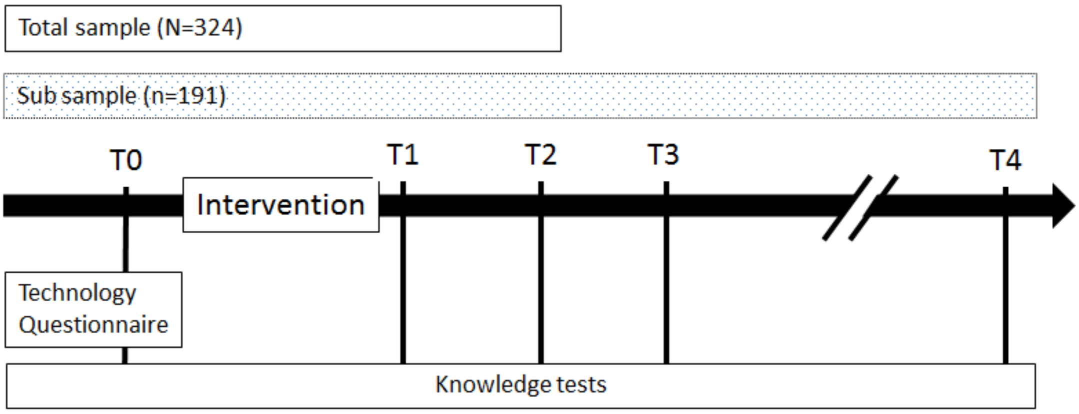

Fig. 2: Schedule of questionnaire implementation.

The knowledge test consisted of 30 items, subdivided into three category groups covering issues of our seminar module (10), aquarium module (10) and of general knowledge about bionics from both modules (10). Examples of items of the sub-modules are shown in Table 2. Appendix D contains the complete questionnaire. At each testing point, the questions and possible responses were randomly reordered. Analysis of knowledge was based on sum-scores, with correct answers coded as “1”, incorrect ones as “0”.

Tab. 2: Examples of knowledge test items, (C) indicates the correct answer.

Module	Example Questions	
Aquarium-Module	Which communication medium do dolphins use? a) ears b) lateral line organ c) Sonar (C) d) whiskers	What kind of bionics application employs the communication system of dolphins? a) underwater communication of divers b) tsunami pre-warning system (C) c) aircraft system in airplanes d) radio frequency
Seminar room-Module	What is the lotus effect? Plants ... a) capturing small flies. b) protected from parasites by glue. c) with very shinny surface due to waxes. d) with water-repellent. (C)	Rodent teeth are a bionics model for... a) forks. b) knives. (C) c) plates. d) teeth washing.
Combination-Module	If someone wants to make a bionics invention, he needs to be... a) an engineer. b) inspired by nature. (C) c) especially smart. d) inspired by art.	Bionics is... a) a sustainable technology. b) a technology for organic food production. c) idea transfer from nature to technology. (C) d) technology from a biological point of view.

A test-retest sample (*n*=47, age *M*=12.3, 27 girls, 20 boys) completed the knowledge tests at T0 and T1 without participating in our bionics module.

Statistical analysis

For the statistical analysis SPSS 23 was used. Assuming the central limit theorem, we used parametric tests (Field, 2013). Item difficulties were computed as the number of students who gave the correct answer. Sum scores to the whole module of 30 items and to the sub-modules (labeled seminar room, aquarium and combination) were analysed via repeated measurement ANOVAs. For the pairwise comparisons at the various testing points we used post-hoc testing with a Bonferroni correction.

For the analyses of the retest group we used a paired t-test. The Pearson correlation coefficient was employed to quantify the relationship of knowledge levels to the TQ subscales mean scores.

Results

Reliability scores of all 30 knowledge items were reasonable (except at T0 (αT0=.541), T1 (αT1=.702), T2 (αT2=.778), T3 (αT3=.815) and T4 (αT4=.761).

Item difficulties

Item difficulties (Figure 3) ranged from .14 to .87 presenting a suitable range of simple to difficult (a low score indicates a difficult item, a high score simple one). We used the item difficulties in the pre-knowledge test to see if the difficulties of the items were distributed normally. The simple questions represent reproduction, the middle rated are reorganization and the difficult question are transfer attainment. The Kolmogorow-Smirnov-test showed a normally distributed sample (p=.200) of item difficulties at T0.

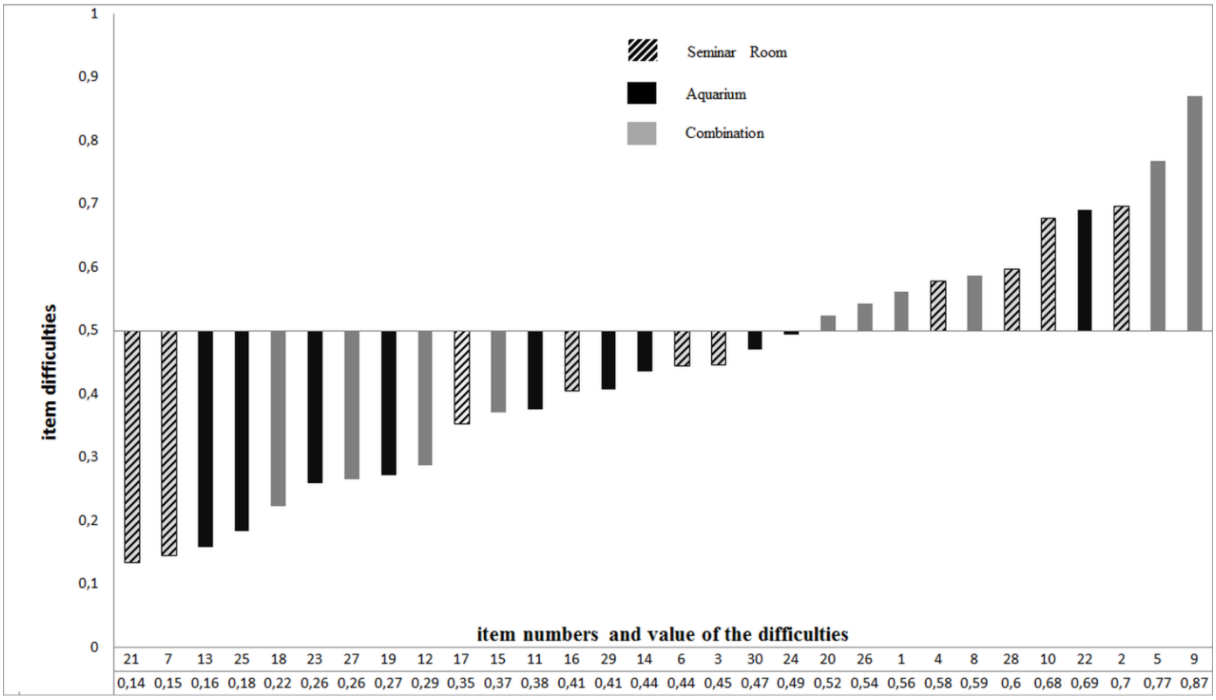

Fig.3: Item difficulties displayed for all 30 individual items (a low score indicates a difficult item, a high score simple one).

Change in knowledge in the module and the sub-modules

Change in knowledge was observed in the whole module as well as in all sub-modules. The lowest scores are at the pre-knowledge level, followed by an increase directly after participation and a decrease 6 weeks later, which however remains higher than before intervention:

Mean knowledge scores (*M*) and standard deviation (*SD*) differed significantly: between the 3 different measurement points T0 (*M*=13.35, *SD*=3.82), T1 (*M*=20.31, SD=3.97) and T2 (*M*=17.20, *SD*=5.20) (Figure 4) in the total module (*F*(1,925,621.857)=368.57, *p*<.001, omega=.0.09) for the total sample (*n*=324). For the total module, Mauchly`s test showed violation of the assumption of sphericity,: chi-square (2)=14.78, therefore, degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity. The pairwise comparison using post-hoc test and Bonferroni correction showed an increase of mean knowledge, both short-term (T0 to T1; *p*<.001) and medium-term (T0 to T2; *p*<.001).

The seminar room subunit ($F(2,646)=199.681$, $p<.001$, omega=.92), aquarium ($F(2,646)=324.273$, $p<.001$, omega=.87) and the combination ($F(2,646)=71.854$, $p=<.001$, omega=.97) showed significant differences in mean knowledge scores. All sub-modules started from a low level before the intervention T0 (seminar room: (M=4.49, SD=1.74); aquarium: (M=3.82, SD=1.62); combination: (M=5.04, SD=1.97)) to highest levels directly after intervention T1 (seminar room: (M=6.91, SD=1.73); aquarium: (M=6.88, SD=1.73); combination: (M=6.52, SD=1.71)) and dropped again after 6 weeks to T2 (seminar room: (M=5.69, SD=2.09); aquarium: (M=5.58, SD=2.15); combination: (M=5.94, SD=2.04)). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results: Knowledge increased short-term (T0 to T1; $p<.001$) and mid-term (T0 to T2; $p<.001$) for all three sub-modules. Knowledge dropped from testing point T1 to T2 in all sub-modules, and in the total module (T1 to T2; $p<.001$).

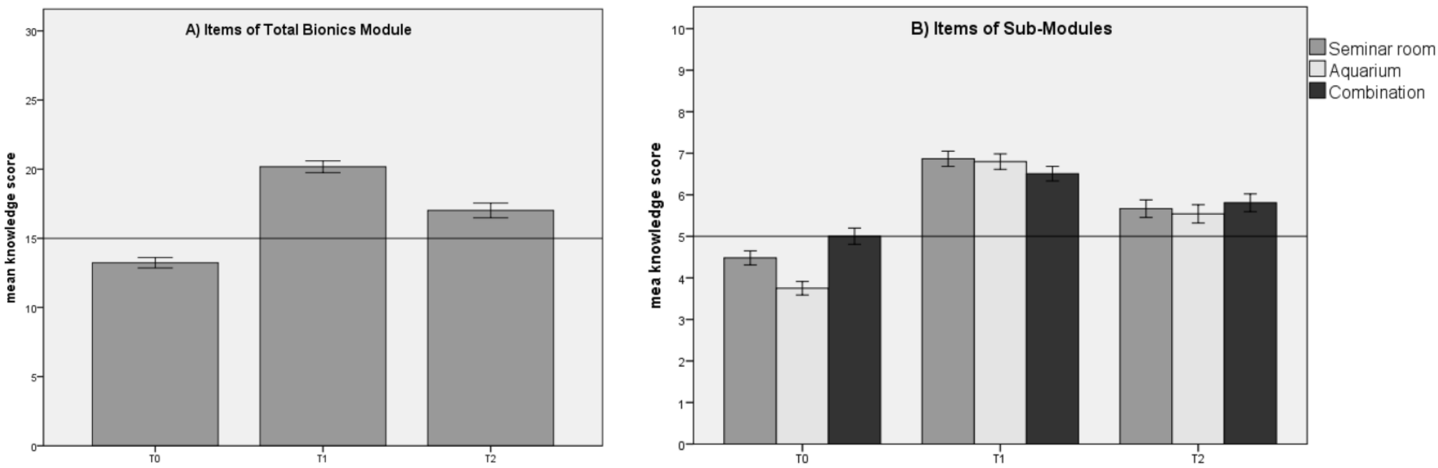

Fig. 4: Mean knowledge scores of the total module at three different testing points with the total sample A) Mean knowledge scores of the total module Bionics; B) Mean knowledge scores of all three sub-modules: seminar room, aquarium and combination with the total sample; Bars are 95% confidence intervals.

Long-term knowledge after one year

A sub-sample of *n*=191 completed the questionnaire five times within one year, over which long-term knowledge is also consistent. The lowest scores are again in the pre-knowledge level, followed by an increase directly after the participation and a decrease six weeks later, which is however higher than before intervention. The following knowledge retention scores after twelve weeks and one year after participation remain at the six-week level.

The repeated measurement ANOVA showed significant differences in the total module (F(3,325,631,827)=84,227, p<.001, omega=.95), the seminar (F(3.575,679.205)=52.377, p<.001, omega=.95), the aquarium (F(3.652, 693.795)=83.624, p <.001, omega=.92) as well as the combination module (F(3.843,730.172)=24.454, p<.001, omega=.98). For the total module chi-square (9)=86.401,the aquarium module; chi-square (9)=41.920, the seminar room module chi-square (9)=53.057 and the combination module chi-square (9)=24.032, Mauchly`s test showed violation of the assumption of sphericity, therefore degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity. The knowledge mean scores increased from T0 to T1, dropped at T2 and remained constant at T3 and T4 (see table 3) in all sub-modules and in the total module (Figure 5). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results. Knowledge increases short-term (T0 to T1; p<.001, mid-term (T0 to T2; p<.001), mid-mid-term (T0 to T3; p<.001) and also in the long-term (T0 to T4; p<.001) in all sub-modules and in the total module (Table 3). Only in the combination module did the mid-mid-term (T0 to T3; p=.118) and long-term (T0 to T4; p=1.00) knowledge level not differ significantly. Knowledge level dropped from T1 to T2, T3 and T4 (T1 to T2; p<.001, T1 to T3; p<.001, T1 to T4; p<.001) in all sub-modules and in the total module. The knowledge mean score remained constant after T2 and showed differences to T3 neither in the subscales nor in the total module (seminar room module T2 to T3; p=1.000, aquarium module T2 to T3 p=1.000; combination module, T2 to T3; p=.064; bionics module T2 to T3; p=1.000). The mean knowledge score showed no change between T3 and

T4 (seminar module T3 to T4; p=.541, aquarium module T3 to T4 p=.305; combination module T3 to T4; p=1.000; bionics module T3 to T4; p=.245). Knowledge levels dropped after T1 and seemed to remain constant for a one year time period (T4).

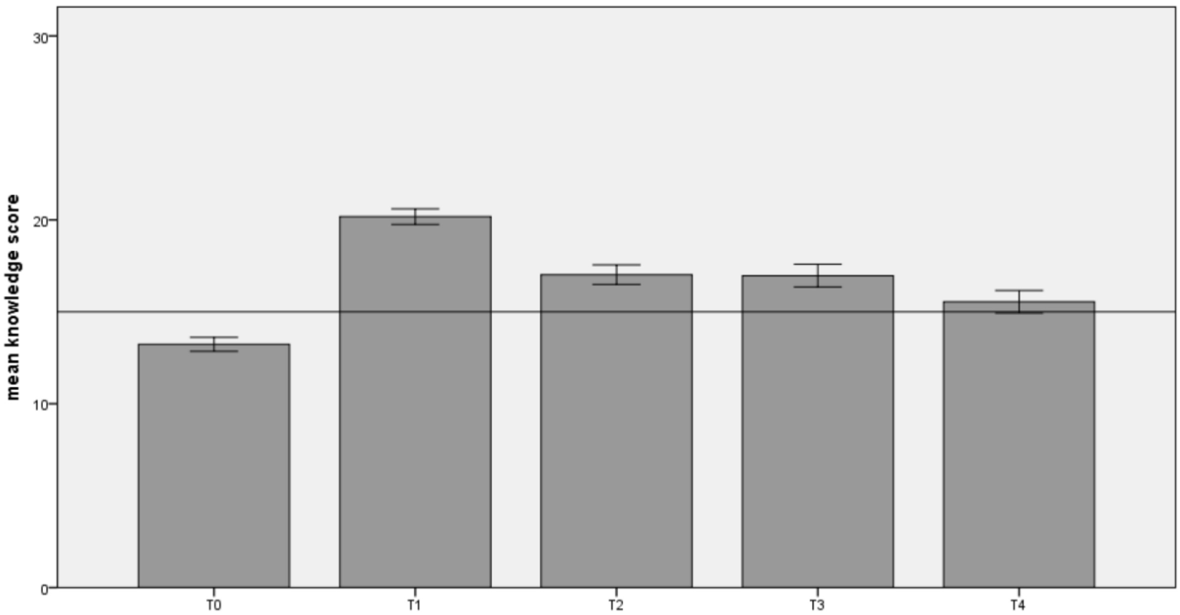

Fig. 5: Mean knowledge scores of a sub-sample for the total module at 5 different testing points with the sub-sample; Bars are 95% confidence intervals.

Tab. 3: Means and standard deviations of the items in the modules.

Module	***T0***	***SD***	***T1***	***SD***	***T2***	***SD***	***T3***	***SD***	***T4***	***SD***
Total Module	13.57	3.87	20.52	3.86	17.37	5.22	16.92	5.71	15.88	4.84
Seminar room	4.58	1.74	6.96	1.69	5.71	2.10	5.73	1.99	5.39	2.01
Aquarium	3.82	1.64	6.87	1.76	5.60	2.19	5.55	2.24	5.15	2.04
Combination	5.17	2.02	6.69	1.64	6.05	2.05	5.63	2.27	5.35	1.88

The test-retest sample completed the knowledge tests showing no difference in response patterns: p=.785; T0 (M=11.53, SD=2.49); T1 (M=11.67, SD=3.54).

Relationship of knowledge to technology

The correlation of the modified TQ and knowledge at T0 showed significant effects at all measurement points and in all sub-modules (see table 4). Both TQ sub-scales (interest and social implications) showed a similar pattern. The pre-knowledge and the technology sub-scales showed a significant relationship.

Tab. 4: Correlation coefficients between the TQ sub-scales interest and social implications and the knowledge at T0.

Knowledge in Sub-modules		***Aquarium-Module***	***Combination-Module***	***Seminar room-Module***	***Total Module***
TQ sub-scale interest	Correlation coefficient	.443***	.419***	.199***	.496***
	Sig.	<0.001	<0.001	<0.001	<0.001
TQ sub-scale social implication	Correlation coefficient	.315***	.478***	.433***	.576***
	Sig.	<0.001	<0.001	<0.001	<0.001

Discussion

A bionics module demonstrated its potential to significantly increase short-, mid- and long-term knowledge levels: This is true for the total module as well as for the aquarium sub-module (focusing on living animals) and the seminar room sub-module (introducing hands-on examples). Students acquire knowledge of bionics in the different dimensions of content knowledge. There are several possible explanations for this knowledge acquisition.

Reasons for knowledge acquisition

Cooperative learning environments apparently bring students together and encourage internal discussion, thus leading to a deeper understanding. Geier & Bogner(2011)have shown that students evaluated cooperative learning forms more positively when they were interested in a topic and were not stressed in a station-based learning approach. Compared to traditional classroom learning settings, cooperative learning approaches seem to lead to better knowledge acquisition and better problem-solving abilities. Our learning stations based on cooperative learning which leads to long-term effects. Gillies (2004) described students as better learners in a structured group compared to an unstructured one. Social skills and science thinking in particular are improved by cooperative learning (Lord, 2001), which is of special importance to our outreach intervention in a zoo, which was based on hand-on stations, known to arouse interest and motivation (Poudel et al., 2005).

In accordance with the constructivist view, any student-centered work with hands-on material provides an optimal way of creating knowledge and offers substantial and sustainable learning benefits (Mayer, 2004). A hands-on learning circle is often regarded as an optimal way to promote individual learning, as it supports interest and motivation of students most effectively (Poudel et al., 2005). Elbadawi, McWilliams, & Tetteh (2010) have shown the potential of hands-on approaches to increase knowledge significantly in comparison to normal lecture-based approaches. Hands-on activities in combination with cooperative learning opportunities often yield successful knowledge acquisition in testing interventions with pre- and post-test design schedules (Bilgin, 2006). Student-centered programs often generate high cognitive achievement potential even in long-term situations (Schmid & Bogner, 2015).

Also the knowledge could be influenced by the out-of-school learning scenario of our bionics module. Out-of-school-learning activities, such as visiting zoos, aquaria or science centers, are regarded as providing useful additional benefits in learning and understanding science and acquiring knowledge (e.g. Sattler & Bogner, 2016; Langheinrich & Bogner, 2016). McClafferty & Rennie (1995) listed potential influences of successful visits, such as pre-knowledge levels, social learning forms, previous experiences with out-of-school visits, cognitional levels of students and, of course, teachers and instructors. Outreach learning in general implies a sustainable increase in knowledge (e.g., Bogner, 1998; Meissner & Bogner, 2011), which explains our decision to combine a seminar room setting with a zoological enclosure setting (with living animals). However, both modules showed similar results and we were not able to build upon a possible novelty effect. Davidson et al. (2010) pointed to the importance of teacher preparation before a zoo visit. In our case, a pre-group phase was intended to ensure this precondition, although for logistic reasons we provided this after arrival at the zoo. Nonetheless, with good preparation it is possible to guide students into a positive learning atmosphere so that they learn despite distractions.

Long-term knowledge persisting over one year

Randler, Baumgärtner, Eisele, & Kienzle (2007) as well as Sattler & Bogner (2016) demonstrated good achievement potential in short- and long-term knowledge in zoo instruction. The first study applied a workstation program about bird species in a zoo, following a pre-, post- and retention-test design. The retention test, nine weeks later, indicated that the students know more than in the pre-test test but less after nine weeks. However, the control group also showed a significant knowledge increase in the retention test, which the authors explained by schoolyard contacts that had allowed discussion of classroom matters. The control group visiting the zoo without treatment unexpectedly showed greater interest, well-being and contentedness than the treatment group. Such circumstances are assumed to influence cognitive achievement enormously: It would be interesting in long-term studies to discover how much information was exchanged in the schoolyards. If students compared notes about their zoo experiences new knowledge acquisition could result. Nevertheless, most pre- and post-test approaches in the literature apply one or two follow-up measures to check knowledge after an intervention (Meissner & Bogner, 2011) . Hence we constructed a testing schedule with three follow-up retention tests after six, twelve weeks and one year. The results seem to follow the pattern of most of other studies: a short-term peak directly after an intervention is followed by a subsequent long-term decrease (Langheinrich & Bogner, 2016) . In the literature, studies over such a long time are very rare: For example, Schmid & Bogner (2015) tested after twelve weeks, and reported a constant level of knowledge. Similarly, Fančovičová & Prokop, (2011) showed that an outdoor school day increased knowledge even after three months compared to a control group. Bogner (1998)recorded the knowledge level half a year or more after an intervention and reported similar results: knowledge level seemed to remain constant within one month. Our results interestingly show even after a time span of one year that knowledge level remains constant. A one-year effect of a half-day program is a striking result which should be recognized by curricula developers.

Ultimately, it could be a relationship between the bionics topic, the cooperative learning scheme, the hands-on station and the outreach area, that supports cognitive achievement even after one year. An additional point in our study is the post-group phase at an exhibition, where repetition strengthened the acquired knowledge. The usual logistic problems make testing schedules after one year very difficult to realize, but any achievement of long-term knowledge gain is welcome. Any study of long-term knowledge needs to demonstrate memory retention after a longer time span, for example of one year.

Bionics as a link between interest in technology and knowledge acquisition

Our intervention bionics assumes a link between technology and science. Bionics is an aspiring science which has the potential to foster interest and generate content knowledge (Neurohr & Dragomirescu, 2007). Technology preferences show high scores for interest and for applications of technology. As knowledge and interest in technology are related, high interest in technology produces high knowledge scores and low interest may indicate lower ones. It is therefore relevant for a learning process that students with higher interest scores are more likely to know more and thus able to profit from their greater knowledge.

Education in technology cannot keep up with the fast development of technology in our daily lives. A study in multidisciplinary fields like bionics needs to be promoted to increase interest and motivation. George (2000) described the science self-concept and the attitudes of peers as the most influential of attitudes towards science, while the influence parents is small. However in our study, a whole peer group needs to become motivated and interested in science contexts. Interest in technology may interact with long-term knowledge. When teachers are aware of attitudes towards science, teaching methods can be adjusted and improved interest achieved (Lovelace & Brickman, 2013). Urban students in particular are thought to adhere to more negative attitudes towards science and scientific careers (Zacharia & Barton, 2004). Another influence on positive attitudes towards science may lie in the knowledge of the teachers involved (Rohaan, Taconis, & Jochems, 2010). Another approach may connect teachers with scientists to bring real technology into school and hence to improve technology education (Stein, Ginns, & McDonald, 2006). Additionally, science, society and technology show a relationship to knowledge levels in technical advances (Bouras & Albe, 2008). Educational initiatives with a technically-based focus (for instance on bionics) may convince more students to study science or to choose science careers. Mc Robbie (2000) described self-reliant projects as options to increase knowledge of technology; he also mentioned that these projects should first be experienced by teachers, so that they can achieve the same awareness as their future students. As bionics is purported to nurture the technology of tomorrow, introducing it to students as early as possible may be advisable.

Limitations of the study

The study is a one-day-learning program, so we only could see that the knowledge increased directly after program participation, but we couldn’t exclude other potential input after our intervention in the zoo. The retention tests after 6, 12 weeks and after one year could be influenced by other factors, which we couldn't measure. Future studies need to use an appropriate questionnaire to monitor possible factors. Another aspect is we did not observe individual student knowledge scores. Differing student demographics could not be measured, because of data privacy regulations. These potential limitations remain.

Conclusion

In summary, an outreach intervention in a zoo provides a good learning environment especially for the long-term transformation of knowledge – provided that appropriate modules are offered. A prior interest in technology may substantially help to build upon prior knowledge. The combination of an authentic environment of a zoo, combined with seminar room instruction and an augmenting module in a public exhibition apparently arouses interest. With the help of living animals and hands-on issues, bionics may become relevant to a student’s real life. Of course, our study is just one way to bring bionics, technology, biology and science into school contexts, but apparently it provides a promising starting point to further promote STEM in the young generation.

Declarations of Interest:

Conflict of Interest: The authors declare that they have no conflict of interest.

The article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere.

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Appendix A

Shortened Technology Questionnaire

	Interest of Technology
I1	I am interested in technology.
I2	I would like to learn more about technology.
I3	I would like a career in technology later on.
I4	I like to read books and magazines about technology.
I5	I would like to join a hobby club about technology.
	Social implications of technology
S1	Technology makes the world a better place to live in.
S2	Technology has brought more good things than bad things.
S3	It is worth spending money on technology.
S4	Inventions in technology are doing more good than harm.
S5	Technology is needed by everybody.

Appendix B

Workstation Aquarium Module

Appendix C

Workstation Seminar room Module

Appendix D

Knowledge Questionnaire

Module	***Example Questions***	
Aquarium-Module	Dolphins uses for their communication: a) A signal analogous to the human voice. b) It's ears. c) A signal that does not occur in nature a second time. d) A combination of different signals. (C)	What kind of bionics application employs the communication system of dolphins? a) underwater communication of divers b) tsunami pre-warning system (C) c) aircraft system in airplanes d) radio frequency
	The dolphin's fin structure is the same as by ...? a) dinosaur.. b) reptiles. c) mammals. (C) d) d) fishes.	The mucus –ridden layer of the fish serves the ? a) better movement in the water (C) b) defense against human enemies c) camouflage d) reproduction
	Why is the dolphin a fast swimmer …? a) because it is a very shy animal. b) because it's a prey. (C) c) because it has many animal enemies. d) because he has to escape.	The "dolphin snout" is most commonly found at ...? a) Cruise ships. b) Tankers. (C) c) Sailboats. d) Pirate ships.
	By a pear-shaped bow, ships ...? a) save fuel. (C) b) give out a warning for dolphins. c) accumulated fuel. d) improve the outward appearance.	What element is transferred to the pear-shaped tower on ships? a) The principle of the sonar system of dolphins. b) The construction of the dolphin's mouth? (C) c) The resemblance of the fin shape. d) The communication of dolphins.
	Which communication medium do dolphins use? a) Ears b) Lateral line organ c) Sonar (C) d) Whiskers	With the Fin Ray effect, ... is transferred to the technical application. a) Each component b) Surface structure c) Substance d) Principle (C)

Modul	Example Questions	
Seminar room-Module	What is the lotus effect? Plants ... e) capturing small flies. f) protected from parasites by glue. g) with very shinny surface due to waxes. h) with water-repellent. (C)	Rodent teeth are a bionics model for… e) forks. f) knives. (C) g) plates. h) teeth washing.
	Why can geckos almost everywhere hold on? a) because it has adhesive on the feet. b) because it is quite weight light. c) because it has a special structure of the footplates. (C) d) because he has claws to hold.	The Eiffel Tower in Paris is bionicaly imitated by … a) fingers. b) bones. (C) c) brawn. d) nerves.
	What is the benefit of a bionicaly optimized component modeled on the "fin ray effect"? a) it adapts flexibly to any object. (C) b) it remains rigid. c) it deforms after strong pressure exertion. d) it remains exactly as it is.	The Fin Ray effect finds application in the ...? a) robotics. (C) b) aerodynamics. c) kinetics. d) motor activity.
	The hook-and-pile fastener is an bionics example inspired by ? a) blossom b) flower stalk c) fruit (C) d) leaf	How is the shark skin built up? a) from many small sheds. b) from many small teeth. (C) c) from a mucus-ridden layer d) from many small hairs.
	What is bionics in the shark skin-effect? a) the operation. b) the motor skills c) the form d) the surface structure. (C)	The bionics of the shark skin find application at? a) caps. b) wellington boots. c) swimming suits. (C) d) jackets.

Module	*Example Questions*	
Combination Module	If someone wants to make a bionics invention, he needs to be... e) an engineer. f) inspired by nature. (C) g) especially smart. h) inspired by art.	Bionics is... a) a sustainable technology. b) a technology for organic food production. c) idea transfer from nature to technology. (C) d) technology from a biological point of view.
	The streamline shape is a central research area in bionics because ...? a) many buildings correspond to this form. b) the flow characteristics are improved. (C) c) whose principle of effectiveness can exhaust whole houses. d) the surface structure is used in the construction of modern cars	Bionics is composed of the following words: (9) a) biology and robotics b) biology and technology (C) c) biology and nickel d) biology and gothic
	The streamlined shape has an ideal ……..shape. a) spherical b) drop-shaped (C) c) box-shaped d) elongated	The biological phenomenon of the streamlined form is applied to ...? a) hook-and-pile fastener b) optimized components. (C) c) technical grippers d) buildings.
	Which animals have the Fin Ray effect? a) reptiles. b) mammals. c) fishes. (C) d) birds.	What species of animal has breast-, back-, belly-, anal and tai- fin? a) Dolphin b) Sea lion c) Manatee d) Trout (C)
	The streamline shape …? a) doubles the resistance. b) increases the resistance. c) clears the resistance. d) minimized the resistance (C)	In which bionic example is the form transferred to the technical application? a) Ventilation systems based on the termites b) Fin ray effect (C) c) Gecko- adhesion principle d) Shark-skin-effect

5.6 Teilarbeit D

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How a hands-on BIONICS lesson may intervene with science motivation and technology interest

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How a hands-on BIONICS lesson may intervene with science motivation and technology interest

Abstract

Science is supposed to raise and support young children's interest as early as possible, at the latest at the beginning of secondary school. Our empirical study monitored individual motivation levels towards science of 6th graders by applying established measures to 324 students (age M=12.2 years, 189 girls, 135 boys). The first empirical measure consisted of the Science Motivation Questionnaire (SMQ), the second of the Technology Questionnaire (TQ). Our lesson consisted of a student-centered outreach module about bionics within a zoological garden in combination with related exhibition. Measurement was conducted two weeks before (T0), directly after (T1) and six weeks (T2) after program participation. The factor structure of the SMQ-II we obtained showed a major difference to the published structure: our young sample couldn't differentiate between intrinsic motivation (IM) and self-efficacy (SE). Moreover, the expected two subscales merged into one which we labelled self-confidence (SC). The other subscale "grade motivation" followed the expected factor structure of the original scale. While this latter subscale was unaffected by our intervention, the sub-scale SC peaked directly after program participation, but unfortunately did not sustain this shift over a six week time period. There were no gender differences at any testing point. Science motivation correlated at a low level with technology interest but failed to correlate with social implications of technology.

Keywords science motivation; factor structure; gender issues; technology interest; bionics module

Introduction

Science and technology are omnipresent in daily life (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). Therefore, a scientific understanding is needed, young people need to familiarize themselves with the increasing penetration of science and technology in our lives (DeBoer, 2000). The scientific literacy paradigm seems an appropriate framework with its potential to support individual needs, as any level of scientific literacy may affect decisions related to science (Miller, 1983). Understanding dependencies is of importance for both the societal and the individual levels (Laugksch, 2000). Scientifically literate individuals tend to feel more competent regarding technology and science in everyday life, although the social, moral and intellectual attainments may need separate attention (Laugksch, 2000). School curricula should prepare children appropriately and sufficiently (ISB, 2004). In consequence, the aim of science education must be to support scientific literacy: DeBoer (2000) declared teaching science and building scientific literacy as the most important goal to prepare best for working life as well as for most other circumstances including becoming a critical consumer of information. It also may help to better understand public discussions about science as well as potential relationships between science and technology. It is alarming that interest, attitudes and motivation of students in the scientific fields seem to drop consistently during school attendance (Osborne, Simon, & Collins, 2003).

Motivation is a well-researched issue with over 100 different definitions even 35 years ago (Kleinginna & Kleinginna, 1981). Today there is general agreement on three major issues: (i) many internal aspects contribute to motivation (psychological and phenomenological), (ii) other aspects deal with functional processes, and (iii) the comprehensive nature of motivation. Motivation in the literature is also understood as dependent on self-efficacy, on beliefs in control as well as on the capability to perform a duty, and self-responsibility building upon individual achievement potential (Pintrich & De Groot, 1990). Self-efficacy is assumed to effect academic accomplishment in various ways (Pajares, 2002). While self-regulated learning is supposed to influence motivation (Zimmerman & Schunk, 2008), its integration into teaching approaches is regarded an essential need. Although ‘motivation to learn science` is defined as ‘an internal state that arouses, directs, and sustains science-learning behavior’, its impetus often seems to be lost during school time (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011, S.1160). Therefore, educators need to support motivation and to bring interest into classrooms again. For designing educational programs, knowledge about presumed levels of motivation may support learning and understanding science. A brief and valid assessment is welcome in any classroom. Glynn, Taasoobshirazi, & Brickman (2009) developed a 30-item Science Motivation Questionnaire (SMQ) (originally for students in college courses; Glynn, Shawn &Koballa, 2006), providing the possibility to measure science motivation of university students. A later reduction to 25-items yielded a modified SMQ-II covering five subscales: intrinsic motivation (IM), self-efficacy (SE), self-determination (SD), career motivation (CM) and grade motivation (GM) by following a well-defined theory of human learning (Albert Bandura, 1986). Schumm & Bogner (2016) first applied this SMQ-II to high school age groups. Similarly, Schmid & Bogner (2017) used three sub-scales of the

SMQ-II for older secondary class students who followed an inquiry approach in an interdisciplinary lesson-unit.

Technology is another trigger in science education as it is present nearly everywhere in our daily life (Ardies et al., 2015). Young people in particular grow up in a society pervaded by social media and communication technology (O'Keeffe & Clarke-Pearson, 2011). Thus, the education sector needs to care of using that tools appropriately (Ardies, De Maeyer, & Gijbels, 2013). It is important, too, that younger students be interested in technology and science. To measure interest in technology and its social aspects, we used the revised short Technology Questionnaire of Marth & Bogner (2017a). We know from the literature that school students with positive experiences at young ages are more successful later in the technology sector (Akpınar, Yıldız, Tatar, & Ergin, 2009). Especially the transition phase from primary to secondary school is regarded as important for science and technology education as this time is one of the most crucial in the lives of children (George, 2006). Motivation for science and technology needs specific promotion to counteract its tendency to decrease during adolescence (Vedder-Weiss & Fortus, 2011). Elementary school children are often not free in their choice of science or even science related activities, as the classroom teacher often decides the content (Simpkins, Davis-Kean, & Eccles, 2006). In high school, students are able to choose science courses as well as out-of-school activities, interacting with free time options like hanging out with friends, working or doing other more interesting things (Larson & Verma, 1999). There is also a distinction between cultures and economies: Asian children tend to attend after-school activities in addition to school commitments leading to better achievement effects (Larson & Verma, 1999). This transition passage, including adolescence, is one of the most crucial periods of supporting interest in science. Larson, Wilson, Brown, Furstenberg, Jr., & Verma (2002) described that transition passage as socially versatile where the most prejudices originate regarding science and learning science. It is worth spending time on science courses and science out-of-school activities to improve the general thoughts and beliefs of young students. Teachers have to be more motivated as well, and need to make experiences more meaningful for school students (Mc Robbie, 2000). It is therefore important to bring school students into contact with technology in science with a variety of programs and educational efforts.

There are in general gender differences in science motivation (Akpınar et al., 2009). Marth & Bogner (2017a) for example showed for boys in low secondary school higher technology interest scores and more social implications of technology. This trend has also been observed with freshmen and adult teachers. Only the social implications of technology seem similar within the teacher cohorts. As science traditionally is still a male-dominated field, women in academic fields like math, science or technology may feel discriminated from the beginning until their graduation, compared to a female-dominated area like art, education or social sciences (Steele, James, & Barnett, 2002). Thus, the likelihood of choosing science careers drops as further constraints like the flexibility of jobs and the traditional role combining family and career aspirations also impact (Frome, Alfeld, Eccles, & Barber, 2006). Moreover, women choosing a science career and participating in a doctoral program may show a lower career aspiration and also a lower academic self-concept (Ülkü-Steiner, Kurtz-Costes, & Kinlaw, 2000). This trend is well-known in STEM (Science, Technology, Engineering and Math) (Blickenstaff, 2005). Despite many available jobs in this sector the number of employed women remains low (Dasgupta & Stout, 2014).

A good possibility to overcome the above shown risk might strictly connect science with technology. Bionics is a substantial research area combining the biology, technology and related sciences to find suitable solutions for the improvement of technology problems, therefore nature can act as a model for technical advantages (Nachtigall & Wisser, 2013). Bionics might be a possibility as it combines science and technology in an innovative way. More and more inventions can be expected. The lotus-effect, for example, is one of the most famous examples with its self-cleaning mechanism due to a wax-coated surface (Neinhuis & Barthlott, 1997). A further example is the shark skin with its optimized longitudinal body axis where small parallel riblets reduce drag Oeffner & Lauder (2012), which reduces wind flow in aircraft (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe, 1997). Existing technologies may be improved or invented through the inspiration of nature. Bringing these interesting and exciting new areas of science and technology into classrooms may create interest in and motivation to learn science.

Given this background, we derived four research questions: 1) Is the SMQ-II Questionnaire suitable for younger age students? 2) Does a one-day intervention influence science motivation? 3) Are there gender differences? 4) Do motivation towards science and interest for technology interact?

Methods

Intervention bionics in the zoo

Our bionics module took five complete school lessons in a zoo (see table 1). Firstly, an instruction booklet containing the relevant material and instructions for the day ensured a similar pre-knowledge. A lesson day started with a teacher-guided unit where the general aims of the day were discussed, and an introduction to the bionics given. Familiarity with the basics of bionics and of biology and technology were assumed for all participants. Each student wrote relevant information into that book and so had a portable guide, as the rest of the day in the zoo was student-centered and teachers only gave answers if needed. Students were organized into small groups of three or four. The following student-centered module was divided into two hands-on sub modules, the Aquarium Module (=AM) and the Seminar Room Module (=SM). Both sub-modules consisted of four workstations.

Table 1: Module phases and description

phase of teaching	***description***	***students activity***	***Time (Minutes)***
pre-group phase	introduction to bionics	teacher-guided learning	25
Seminar room module	seminar room activity	hands-on	85
Aquarium module	concentrating on the living animal directly in the zoo	hands-on	85
post-group phase	exhibition „BIONICUM“	Repetition	30

In the post-group phase, the exhibition `BIONICUM` provided the option to rearrange newly acquired knowledge from the pre-group and group phases by building new cognitive structures with examples from the interactive exhibition: experiments, videos, hands-on and computer-guided learning. For instance, the rodent self-sharpening teeth effect was shown in a video as well as its technical application in self-sharpening knifes. Finally, a dancing and singing robot presented bionics directly as “human model”. All interventions were guided by the same teacher and tutor in order to ensure equality of the module application for all classes.

Sample and study design

324 6th graders (age M=12.2 years, 189 girls, 135 boys) participated in a hands-on guided learning module. The students completed the Science Motivation Questionnaire-II (intrinsic motivation, self-efficacy, grade motivation) three times (see figure 1). The first measurement point was two weeks before our intervention, the second directly after participation and the third six weeks after participation. At T0 additionally the shortened Technology Questionnaire (TQ) consisting of the two subscales “interest in technology” and “social implications of technology” was completed (Marth & Bogner, 2017b).

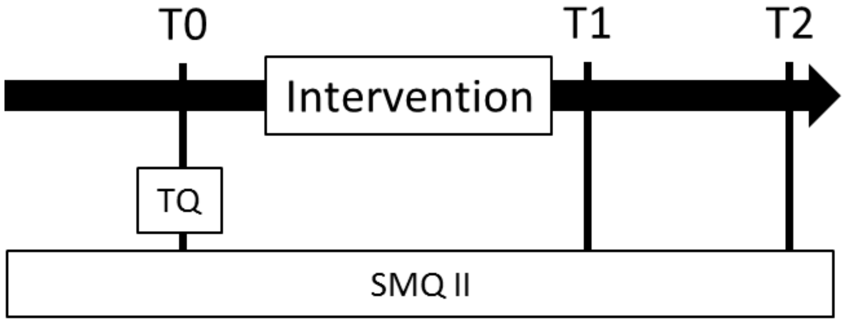

Figure 1: Schedule of questionnaire implementation

Statistical analysis

Statistical analysis was conducted using SPSS Version 23. Using the central limit theorem we used parametric testing methods.

First, we applied an explanatory factor analysis to the SMQ-II item set for visually inspect the similarity to the original scale following a principal factor analysis with oblim and varimax rotation. The suitability of our sample for factor analysis was tested using the Kaiser-Meyer-Olkin test (KMO) (Kaiser, 1970) and Bartlett's test of sphericity. The Kaiser-Guttman (Kaiser, 1960), was employed to determine the number of factors to extract.

For the analysis of the different testing points of the SMQ-II, we used for each subscale (SC = self-confidence, GM = grade motivation) a repeated measurement ANOVA based on mean scores. For pairwise comparison at the different testing points, we applied post-hoc testing with the Bonferroni correction. For the measurement of significant differences between the genders, at each testing point for each subscale we used also the repeated measurement ANOVA above. For the test-rest group we also used an ANOVA for each subscale of the SMQ II. The Pearson Correlation coefficient was used to quantify the relationship of the SMQ II and the TQ subscale (IN = Interest, SO = social implications) mean scores.

Results

Exploratory factor analysis

We subjected the 15 items of SMQ-II (T0) to principal axis factor analysis (PAF). In contrast to the original three sub-scales IM, SE and GM, our analysis extracted two, merging the first two into a factor we labeled "self-confidence (SC)". The Kaiser-Meyer-Olkin measurement of .923 is high (Hutcheson & Sofroniou, 1999), as is Bartlett`s test of sphericity (chi-square= 2436.649; p=<.001) (Field, 2013). By using the Kaiser-Guttman criterion, 51.52 % of the total variance were explained. Oblique and orthogonal rotations yielded essentially the same solution. The varimax factor loadings are shown in Table 2, loadings below .35 are not shown. The percent of variance explained by "self-confidence" (SC) was 42,286%, and 9,243 % for "grade motivation" (GM).The reliability scores were reasonable for all sub-scales at all testing points, ranging from .80 to .89 (SC: T0 (αT0= .897), T1 (αT1=.868); T2 (αT2=.907); GM T0 (αT0=.844), T1 (αT1=.897), T2 (αT2=.895)).

Table 2: Factor loadings from the PAF of the pre-test values of the SMQ II (T0) (Scores under .35 are suppressed)

N= 325	F1	F2
Factor 1: Self-confidence		
1 Learning science is interesting	.727	
2 I am curious about discoveries in science	.734	
3 The science I learn is relevant to my life	.391	
4 Learning Science makes my life more meaningful	.448	
5 I enjoy learning science	.677	
6 I believe I can earn a grade of "A" in science	.673	
7 I am confident I will do well on science tests	.708	
8 I believe I can master science knowledge and skills	.815	
9 I am sure I can understand science	.752	
10 I am confident I will do well on science labs and projects	.762	
Factor 2: Grade Motivation		
11 Scoring high on science test and labs matters to me		.581
12 It is important that I get an "A" in science		.803
13 I think about the grade I will get in science		.791
14 Getting a good science grade is important to me		.904
15 I like to do better than other students on science tests		.461

The mean knowledge scores (M) and standard deviation (SD) differ significantly between the 3 different testing points for the sub-scales from the SMQ II (see Figure 2).

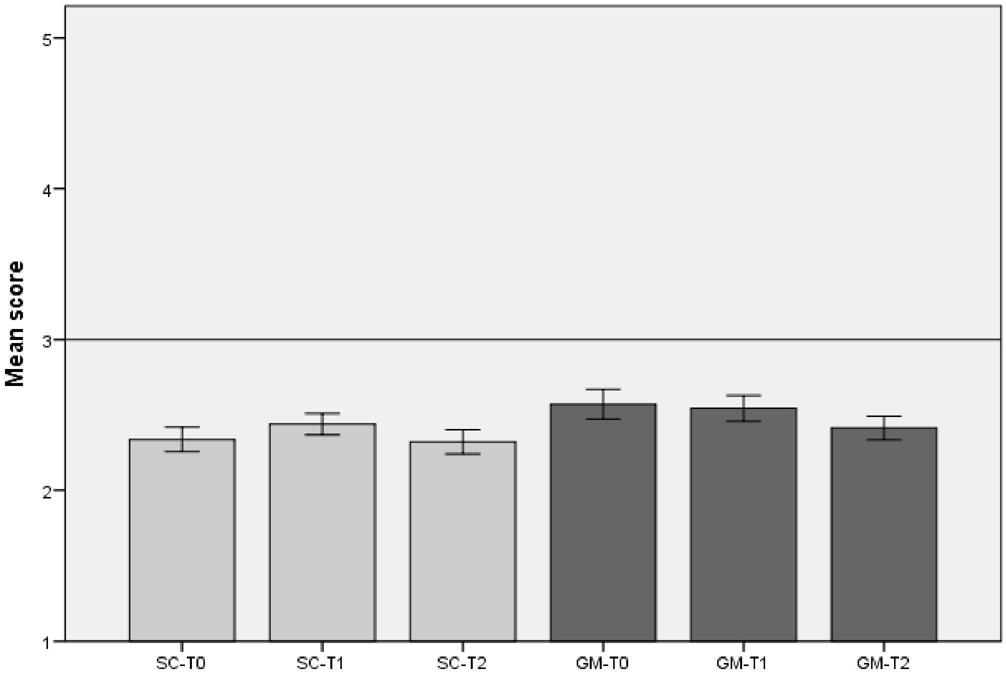

Figure 2: Mean knowledge scores of the 2 different sub-scales SC and GM to testing points T0, T1 and T2; Bars are 95% confidence intervals

The sub-scale SC showed significant differences in the repeated measurement ANOVA (F(1.969,513.930)=6.188, *p*=.002, omega=.90). For the chi-square of the sub-scale SC (2)=7.157 Mauchly`s test showed violation of the assumption of sphericity, therefore degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity (epsilon=.985). The knowledge mean scores increased from T0 (M=2.36 ; SD=.751) to T1 (M=2.45 ; SD=.692) and dropped at testing point T2 (M= 2.32; SD= .772) (Figure 2). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results. SC increased short-term (TO to T1; *p*=.029 and dropped again at testing point T2 (T1 to T2; *p*=.034). Testing point T0 and T2 showed no significant differences (T0 to T2; *p*=1.00).

The sub-scale SC was also analyzed for differences between the female and male participants (see Figure 3). There was no significant effect of gender (F(1.969,513.930)=.263, *p*=.766, omega=.83), indicating that the mean scores from male and female students were similar (male: T0 (M=2.43; SD=.806), T1 (M=2.55; SD=.701); T2 (M= 2.42; SD= .765); female: T0 (M=2.28; SD=.686) to T1 (M=2.35; SD=.670), T2 (M= 2.24; SD= .772)).

For the sub-scale GM, the repeated measurement ANOVA yielded no significant differences (F(1.950,571.275)=.035, *p*=.963, omega=.90). For the chi-square of the sub-scale GM (2)=10.699 Mauchly`s test showed violation of the assumption of sphericity, therefore, degrees of freedom were corrected by using Huynh-Feldt estimates of sphericity (epsilon=.975). Knowledge mean scores stay constant from T0 (M=2.57; SD=.915) to T1

(M=2.56 ; SD=.823) and also to T2 (M=2.56 ; SD= .906) (Figure 2). The post-hoc pair-wise comparison with the Bonferroni correction showed similar results. GM stay constant short-term (TO to T1; *p*=1.00) and also to testing point T2 (T0 to T2; *p*=1.00; T1 to T2; *p*=1.00).
The sub-scale GM showed no difference between female and male participants (see Figure 3): (F (1.950,571.275)=.692, *p*=.497; omega=.80), indicating similar mean scores for male and female students (male: T0 (M=2.63; SD=.922), T1 (M=2.66; SD=.812); T2 (M= 2.60; SD= .888); female: T0 (M=2.50; SD=.905) to T1 (M=2.46; SD=.825), T2 (M= 2.52; SD= .924)).

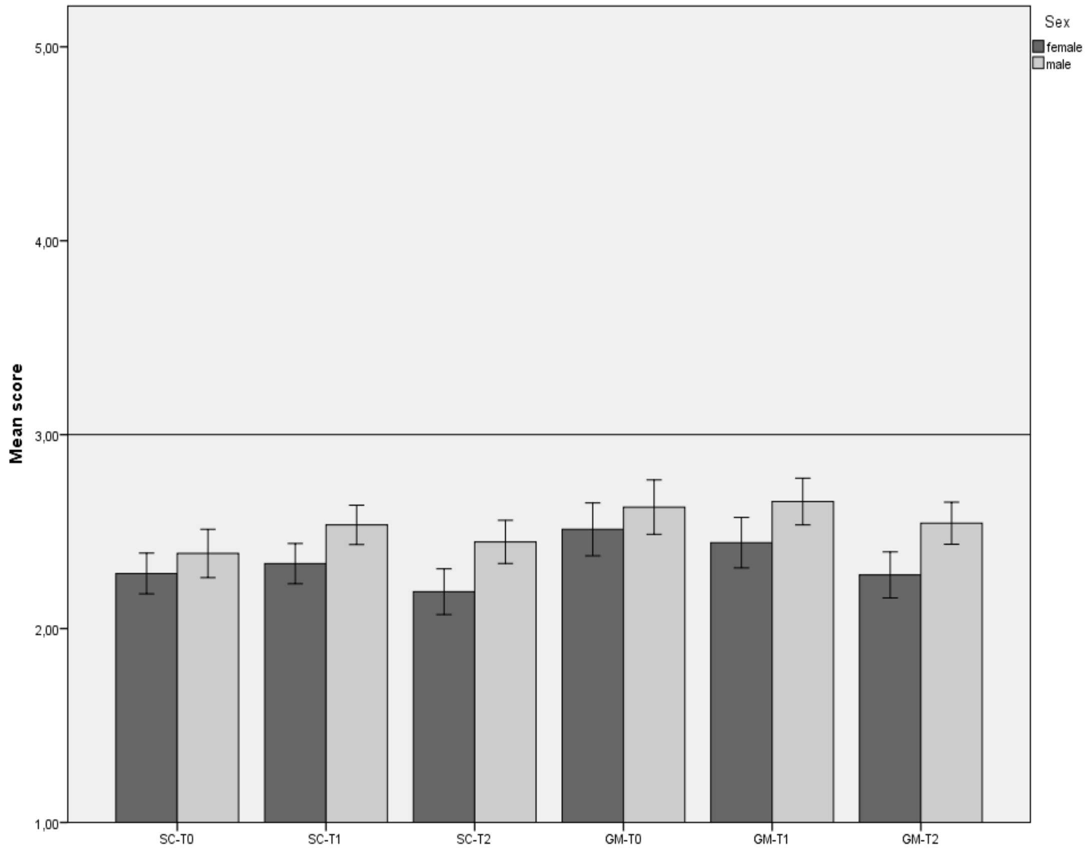

Figure 3: Mean knowledge scores of the 2 different sub-scales SC and GM to testing points T0, T1 and T2 split by gender; Bars are 95% confidence intervals

A non-participant test-retest group yielded in a repeated measurement ANOVA no difference at the different testing points in each sub-scale (SC: (F(1.883,92.250)=.223; p= .787 omega=.90; GM: (F(1.901,285.210)=.711; p= .711 omega=.90).
The correlation matrix of the SMQ-II sub-scales between each other and with the modified TQ is displayed below. The linear slope shows the interrelation among the single correlation factors.

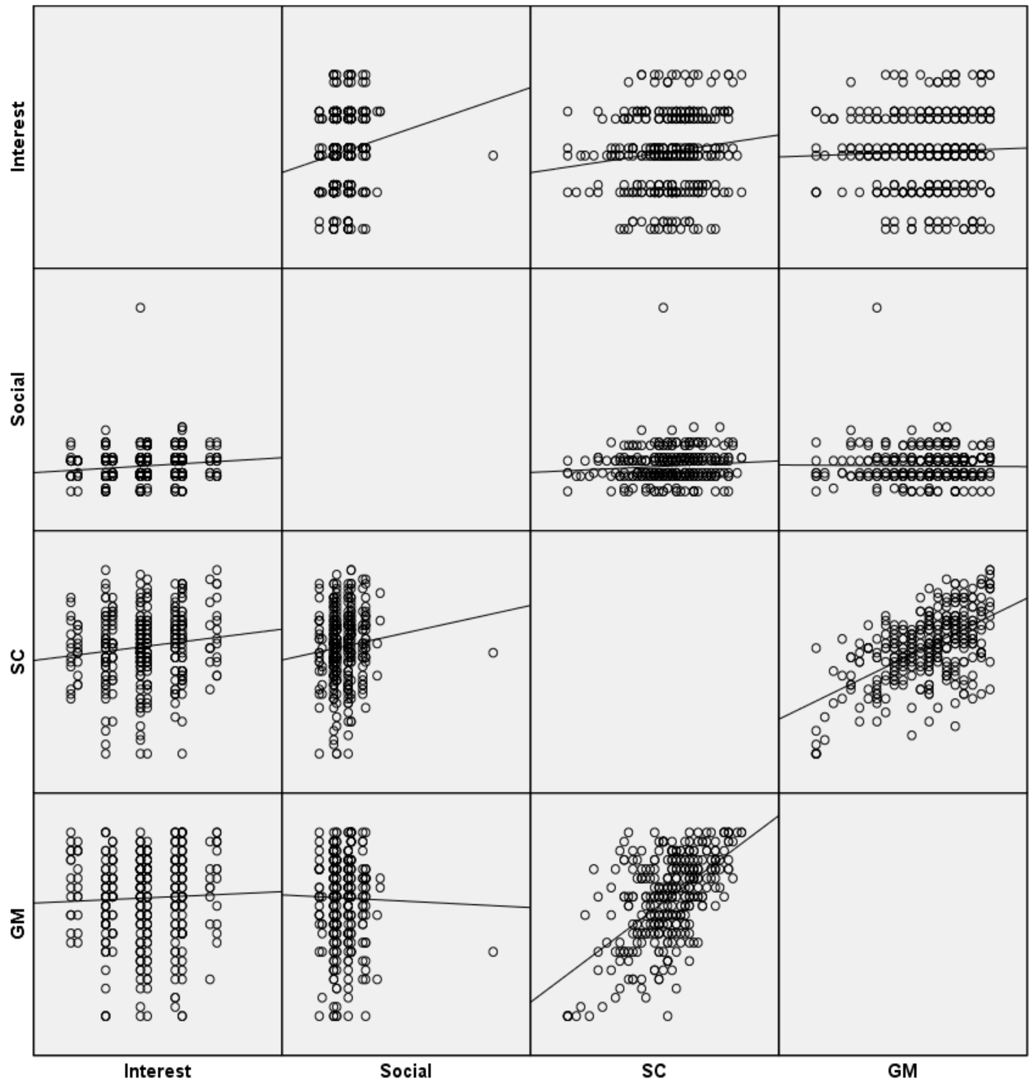

Figure 4: Pearson correlations matrix between the sub-scales SC and GM and sub-scales interest and social of the TQ: plot showing the distribution of the correlations and the positive interrelations

In addition to Figure 4 above the other testing points T1, T2 and T3 were analyzed. The intercorrelation of the SMQ II sub-scales (SC-GM) showed significant effects for all correlations (T0: r=.573 ***, p=<0.001; T1: r=.644 ***, p=<0.001; T0: r=.664 ***, p=<0.001).

The bivariate correlation of the SMQII sub-scales SC and GM with the modified TQ showed no significant differences. The sub-scale "interest" showed only a very low correlation with the sub-scale SC at testing point T0 (p=.024; r=.124; r^2= .015). The sub-scale GM shows no significant correlation either for interest or for social.

Discussion

Science motivation of 6th graders seems to originate in different concepts compared to adolescent or adult subjects: Career-motivation and self-determination still seem far away from reality for 6^{th} graders compared to older samples (Schumm & Bogner, 2016). The “umbrella” term may not need three sub-scales to explain its meaning (intrinsic-motivation, self-efficacy and grade motivation), since younger subjects seem to combine two to form single one: the “umbrella” factor structure for the 10 item-set (intrinsic motivation and self-efficacy) in our younger age-group differed from the earlier reported older structure (freshmen, 10^{th} graders). Apparently the young do not discriminate between intrinsic motivation and self-efficacy. This was an unexpected result as no previous studies have suggested this pattern (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011).

Even Ryan & Deci (2000) had built upon self-determination and explained this with the importance of humans’ development of personality. The original factor analysis was obtained from university students and not for younger participants as in our study. This difference may present the largest effect in the disparity with Glynn et al. (2011). This dependency might be the cause of the merging of intrinsic motivation and self-efficacy. Pintrich & De Groot (1990) have reported self-efficacy and intrinsic values as positively supporting cognitive performance. Also Zimmerman & Kitsantas (1999) reported a high correlation between self-efficacy and school students’ intrinsic interest. We labeled this “umbrella” of intrinsic motivation and self-efficacy as “self-confidence” (SC).

“Confidence in one’s abilities generally enhances motivation, making it a valuable asset for individuals with imperfect willpower” (Benabou & Tirole, 2002 p.871). Philosophers, educators and psychologists see self-concept as the main root of motivation, emotion and social influence; and self-confidence in skills and efficacy may help to increase motivation for different ventures (Benabou & Tirole, 2002). Kleitman & Stankov (2007) reported self-confidence to be a solid predictor of performance accurateness. It’s the key to good performance and the power of endurance in different circumstances to work hard and believe in one’s skills, to win a medal, for example, or perform on stage, be accepted by college, write a great book, do innovative research, set up a company, reduce weight, find a mate, and so forth (Benabou & Tirole, 2002). For us, self-confidence may trigger the ability to reach goals in science and increase self-efficacy beliefs and intrinsic motivation. The connection between self-confidence and motivation is described by Ryan & Deci (2000) who postulated intrinsic motivation and well-being as needs different psychological requirements namely competence, autonomy and relatedness. These components are the key to motivation and achieving goals.

Bandura (1977) pointed to the importance of self-efficacy for reaching a goal and how long motivation needs to last in order to achieve a target. School students may not have belief in self-efficacy in the context of science, as science is not included in primary school syllabi. As self-efficacy is defined as “people's beliefs about their capabilities to produce effects” (Bandura, 1994 p.71), it is largely the perception of the impact of someone’s action that seems affected. Self-efficacy is one of the most important predictors of motivation and success in learning science: as Zimmerman (2000) saw it as basis for achievement resources depending of what the self-efficacy beliefs should measure. In our case, the measurement focus is science motivation, but school students couldn’t express self-efficacy belief for motivation for school careers without knowledge of science. Bandura (1997) pointed out that students with high self-efficacy beliefs show more efforts in challenging a task and work consistently, harder and with greater persistence.

The self-determination theory of Deci & Ryan (1985) differentiated types of motivation, distinguishing between intrinsic and extrinsic motivation: intrinsic motivation is doing something with an inherent will, and extrinsic motivation has to do with goal oriented actions driven by external circumstances. The first may exist in every human, but not every person is intrinsically motivated towards similar tasks or fields (Ryan & Deci, 2000). However, intrinsic and extrinsic motivations belong together: Lin, McKeachie, & Kimm (2001) described intrinsic motivation as linked with better grades as highly extrinsic motivated students do. Therefore, educators should regard not only knowledge as the main educational goal, but also see lifelong learning as an enhancing variable supporting perception and motivational sites to better learn science (Vedder-Weiss & Fortus, 2011).

Sturm & Bogner (2008) for example used the “Intrinsic Motivation Inventory” (IMI) to demonstrate that a student-centered approach is more internally motivating than a traditional school setting. Gerstner & Bogner (2010) on the contrary found no link between motivational aspects and a traditional or student-centered approach. Another study of hands-on learning as opposed to learning in normal school settings showed more well-being and more self-determination in the former (Schaal & Bogner, 2005). The sub-scale “interest and enjoyment” of the IMI showed positive relations to the attitudes towards a cooperative learning setting (Geier & Bogner, 2011). In an outreach laboratory unit, Goldschmidt & Bogner (2015) found higher achievements scores for short- and long-term knowledge for higher motivated participants. In a student-centered learning study of the risks of smoking, Hedler & Bogner (2013) reported a creative learning environment as increasing autonomous motivation and decreasing controlled motivation. Therefore, the self-confidence towards science may provide the possibility to catch someone's interest again and focus the main features of science. In sum, the connection between self-efficacy and intrinsic motivation may offer a good chance for young secondary school students to build the self-confidence in science.

For promotion of science motivation with a one day learning program, a learning intervention might improve the science motivation with respect to self-confidence, as the significant increase after our intervention showed. This is quite in line with Brickman, Gormally, Armstrong, & Hallar (2009) where an increase in self-confidence after an inquiry lab course was reported. In our study in a zoological garden with living animals student-centered learning environments and hands-on material seem to supply an optimal way to increase knowledge (Mayer, 2004). Hands-on learning not only promotes knowledge, but it also effectively supported motivation and interest (Poudel et al., 2005). This conclusion is supported by a meta-analysis of 65 studies where cooperative learning was shown to generate better cognitive achievement and attitudes (Kyndt et al., 2013). Nevertheless, the self-confidence shift we initially observed was not maintained six weeks after participation. Repeated interventions, or especially promoted science related courses and out-of-school activities might keep shifts consistent over time. Science activity participation for example has been shown to predict science perceptions in high school (Simpkins, Davis-Kean, & Eccles, 2006). Parental support provided also needs attention, as parents pass their own attitudes and feelings about science and math on to their children (Jacobs & Bleeker, 2004). The STEM field meets with low interest and motivation in the view of the general public. Especially during the secondary school it dropped enormously, one reason being teacher-student interactions (Kiemer, Gröschner, Pehmer, & Seidel, 2015).

Grade motivation was irrelevant to our intervention as a program day in a zoo earns no grades. One point of such a program is to enjoy the intervention day in the zoo without the anxiety of grade or judgment from the classroom teachers. Terry, Mills, & Sollosy (2008), however, showed students to be more motivated when they do earning grades in such a context. Ryan & Deci (2000) described for extrinsic motivation as referring, making something just because of an expected result. Nevertheless, we generally need to mention that our low scores for self-confidence and grade motivation might be explained by in the age of our participants: young students may show low self-confidence and grade motivation for science because their science education started only one year before the intervention. Schumm & Bogner (2016) worked with cohorts four years older than our sample) and reported much higher science motivation both intrinsically and extrinsically. Similarly, Glynn et al. (2011) reported much higher science motivation for university students. Taken together, self-confidence could be influenced in the short-term and grade motivation unaffected by our intervention.

The lack of gender differences finds support in other studies. Zeyer (2010) or Zeyer & Wolf (2010) reported similar results, concluding that motivation does not matter for learning science by gender. Conradty & Bogner (2008) for example showed for 8^{th} grade girls higher intrinsic motivation scores in scientific topics while Schumm & Bogner (2016) and Obrentz (2012) reported lower self-efficacy scores for girls. Glynn et al. (2011) worked with university freshmen, Obrentz (2012) with college freshmen and Schumm & Bogner (2016) with 10th graders. Our 6^{th} graders represent a transition between childhood and early adolescence with all the biological, physical and metacognitive changes in this stage of life. Differences in lack of self-confidence may suggest this. Similarly, Wigfield (1996) reported for primary school children equal confidence scores in math and science, while middle school children already showed a gender gap. In the literature, a gender difference with lower science motivation scores is expected (e.g., Obrentz 2012; Glynn et al. (2009)) where in first case girls show less self-efficacy and trust in science. As most studies worked with high school or university subjects, our reported lack of a gender gap may convince.

Relationships between technology and science seem complex: Science motivation with its sub-scales self-confidence and grade motivation correlated significantly, in agreement with Glynn et al. (2011) when the different factor structure is not taken into account. Moreover, Glynn et al. (2011), Obrentz (2012) and Goldschmidt & Bogner (2015) have reported a dependence of science motivation on achievement scores. Schumm & Bogner (2016) found small correlations between the motivation of self-determination and the sub-scales of the big-5 “consciousness” and “neuroticism”. Our small correlation between “self-confidence” and “interest in technology” supposes to connect both variables anyway as technology and science are related fields especially in the bionics field (Bannasch, 2009). Mistler-Jackson & Songer (2000) also reported a motivational influence in a technology-driven intervention. Similarly, scientists’ and public thoughts may exert a big influence on the motivation of science and technology (Martín-Sempere, Garzon-Garcia, & Rey-Rocha, 2008). Also, Aikenhead & Ryan (1992) concluded that science included a technology site in our “Science-Technology-Society” as both are belonging together and approximate each other. Fields like bionics build up an appropriate interface as teaching science and technology should be not separated in school classes. Teachers and educators should try also to combine these fields to enhance students’ beliefs and knowledge and to build new cognitive structures supporting scientific literacy and technological know-how.

Conclusion

Knowledge about science motivation offers useful and consistent information in a classroom. Extrinsic motivation (including the motivation to earn good grades) seems to be one of the biggest predictors of school success, a factor which outreach interventions cannot exploit since they do not give grades. Nevertheless, outreach experience offers a chance to raise the general motivation for science. Intrinsic motivation as part of the self-confidence concept in combination with self-efficacy can be exploited with appropriate activities such as field-days, extracurricular programs or out-of-school courses. Innovative issues such as bionics may interact with the variables described (at least our study supported this). When students are interested in STEM in school they were able to take it home and persuade parents or friends of the need for science in modern society. Even if they only inspire themselves, school needs to incorporate STEM education in education of the young generation. Our study is another option to bring science into the school context especially in the students' minds, but it may represent another approach to supporting STEM.

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ANHANG

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Hiermit erkläre ich, dass keine Tatsachen vorliegen, die mich nach den gesetzlichen Bestimmungen über die Führung akademischer Grade zur Führung eines Doktorgrades unwürdig erscheinen lassen.

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Ort, Datum, Unterschrift

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